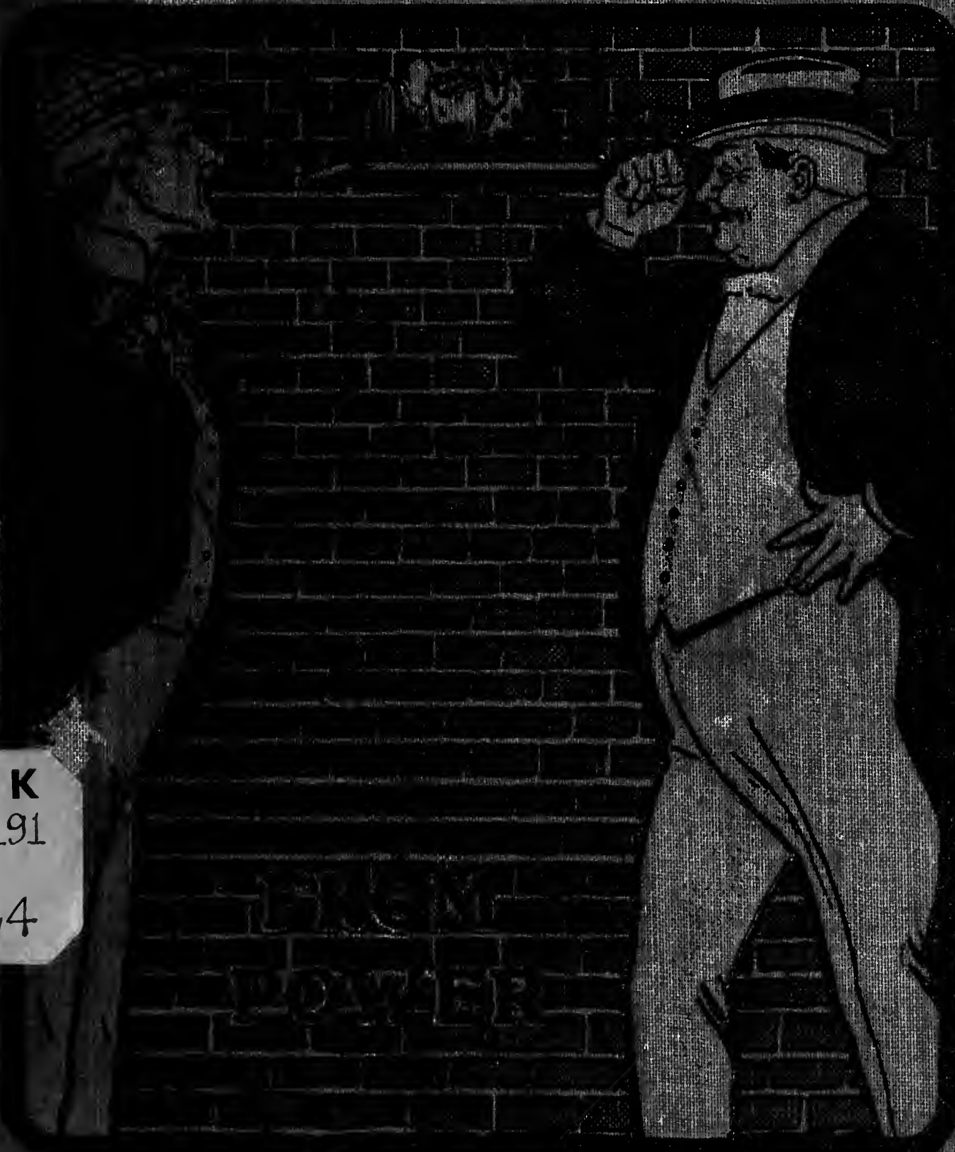
CENTRAL STATION EXPERIENCES



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CENTRAL STATION EXPERIENCES

A series of narratives on the trials
and tribulations of a steam
engineer while learning
to run an electric
station

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WORLD BUILDING
1901

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A DEFECTIVE ARC LAMP.

The water-works plant of the town of Millville had been augmented by an electric lighting plant, comprising a 50-light Brush arc dynamo and two 500-light incandescent machines, with the necessary circuits and appurtenances. The engineer, who was a bright fellow, and had studied as much as his limited opportunities would allow, was without practical experience in the operation of electrical machinery, and was correspondingly nervous over his new responsibilities.

"You see," he confided to Jones, who installed the plant, "I never actually run one of these blamed things, though I've been over to the Watertown station a good deal, and watched 'em running."

"Don't you worry a mite," said Jones; "I'll be through here every few weeks, and I'll always stop off to see how you're getting on," which he did faithfully.

The plant was duly started up by Jones, who remained a week to get the engineer fairly started, and things went swimmingly until one night when the "trimmer," who looked out for the arc lamp circuits, came rushing in and exclaimed:

"The lamps are all upside down; turn her around quick!"

The engineer stared.

"Upside down? I haven't touched 'em. Turn who around—what—"

"They're burning backwards, man; can't you see?"

"No, I can't see. What are you talking about?"

The trimmer had had considerable experience, and explained to the engineer that the current was going through the arc lamps in the wrong direction, making the bottom carbon positive and the top one negative.

"What's the odds, so long as they burn? Might as well let her rip until morning," said the engineer.

"Good Lord, man; you'll burn up all my carbon holders. Can't you change your plugs on the board?"

The engineer felt shaky, but he didn't wish to appear too green, so he sauntered over to the switchboard, followed by the trimmer.

"Yes," he said, with assumed composure, "I s'pose I might."

The board was a simple affair, consisting of two plugs at the

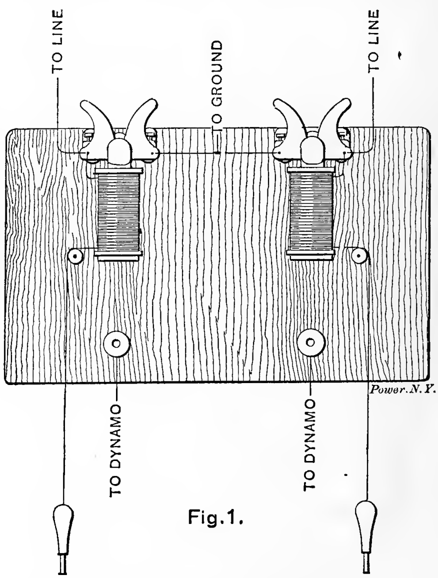


Fig. 1.

ends of flexible cords leading from the circuit lightning arresters, and two sockets connected with the terminals of the dynamo, as shown by the diagram in Fig. 1. This arrangement, Jones had explained, was better than connecting the plugs to the dynamo and the sockets to the circuit, because if the plugs should be hanging free at any time when the dynamo was running, their touching each other could not hurt the dynamo. If they were the dynamo connections, touching them together would short-circuit, and might damage, the machine.

"All you've got to do," suggested the trimmer, who wouldn't have tried to do it for the whole plant, "is to reverse them plugs.

That'll make the positive side negative and the negative side positive."

The engineer pretended to ignore the trimmer's friendly advice, as though it were unnecessary, but he heeded it. Without stopping the engine he closed the field switch on the dynamo, "killing" the field, as Jones had shown him should be done when it was desired to open the circuit for any reason. Then he took out the switchboard plugs and reversed them in the holes, went

"The lamps are all upside down."

back to the dynamo and opened the field switch. The pilot lamp over the dynamo did not light up and the engineer felt a shiver of apprehension pass up his spine.

"What have you done now?" asked the trimmer, ready to lay all the blame for any possible mishap upon someone else.

But the engineer kept his head; although he didn't know what was wrong, he did know that he had done nothing to cause any

serious trouble. So he determined to simply start up all over again, just as he had at lighting-up time.

"Nothing," he replied to the trimmer, "but I think I'll shut down and take a look at her."

Accordingly he shut down the engine, took out the switch-board plugs and gave them to the trimmer to hold in proper position for insertion, so as to avoid getting the polarity mixed up again, and pretended to examine the dynamo for a moment.

"I think she'll go now," he said, without changing a single adjustment, but being careful to see that everything was in its usual condition for starting.

Then he started the engine, went to the board and taking the plugs from the trimmer put them, one at a time, in the sockets. When the second plug went home the pilot lamp struck its arc with a clack and a hiss that gave the engineer's mind mighty relief.

D

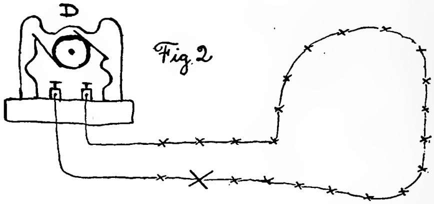


Fig. 2

"Thought that would fetch her," he said carelessly, and he immediately rose several points in the trimmer's estimation.

The lamps were now all right, except one that the trimmer brought in burned up the next morning, and matters went along smoothly up to Jones' next visit. The engineer related the whole occurrence to Jones.

"You opened the field switch while the plugs were in and got no light?" he asked.

"Yes."

"And you stopped the engine and started up with the plugs out, putting them in after the machine was up to speed?"

"Yes."

"Burn up any lamps?"

"One."

"Ah! Let me see it."

"It's gone to the factory for repairs."

"Well, it doesn't matter. Give me a piece of chalk." This was furnished and Jones drew a rough diagram on the floor, like Fig. 2.

"Suppose *D* is your dynamo and the crosses represent arc lamps in the circuit. The big cross means a faulty lamp in which the clutch was sticky and the cut-out defective."

"The one that burned up?"

"Yes. If you had it here you would no doubt find that there was trouble with both the clutch and the cut-out. The chances are that someone neglected to connect the cut-out, or it has become disconnected since the lamp was sent out."

"What did that have to do with the dynamo not 'picking up?'"

"Well, you know what the cut-out in a lamp is for, don't you?"

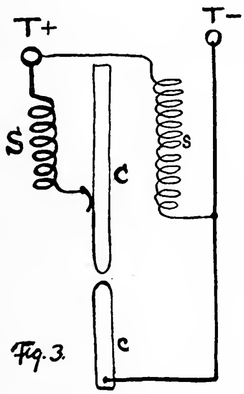


Fig. 3.

"To cut it out of circuit when it gets out of order."

"Yes. Now you know that there are two magnet coils in a lamp."

"Yes, but I don't know why."

"I'll tell you. The one with coarse wire draws the carbons apart and the one with fine wire draws them together. The circuits in the lamp are roughly like this," and Jones drew Fig. 3. "*S* is the heavy wire coil and *s* is the fine wire. *C* and *c* are the carbons. Now the current divides as long as the lamp works properly; most of it goes through *S* and the carbons and a little goes around through *s*."

"What makes it divide unequally?"

"The resistance of each path. Do you know Ohm's law?"

"The current equals the voltage divided by the resistance."

"Exactly. Now if the path through S and the carbons has a total resistance of 5 ohms, and the voltage from $T+$ to $T-$ is 45 volts, how many ampères will go through?"

"Nine."

"Good. Now suppose the coil s has a resistance of 90 ohms, how much current will go through s?"

The engineer scratched his head to fight for time.

"Lemme do it on paper," he finally said.

"No, you don't need to. Suppose the resistance was 9 ohms and the volts 45, how much current would pass?"

"Five ampères."

"Well, now if the resistance is ten times nine the current will be one-tenth of five, which is ——"

"One-half."

"Right. Then we will have, say, 9 ampères through S and $\frac{1}{2}$ ampère through s. This is almost exactly what does flow in practice when the lamp is all right. But if the carbon rod sticks so that the coil s can't feed it down, and the cut-out is balky or disconnected, the arc gets longer and longer, so that less current goes through S and more through s, heating the latter coil and eventually burning it."

"But ——"

"Wait a moment. When you shut down, this lamp had not been going long enough to cause trouble. But when the current was taken off the line, the carbon rod hung up, and your cut-out took a vacation, leaving the lamp just as the sketch shows it. Now when you tried to start up again the only path through that lamp was the coil s, of very high resistance, so that you got no light."

"What then?"

"Well, when you first opened your field switch the dynamo was not excited highly enough to force the full current through that coil, but it would probably have heated it up to the burning point after awhile."

"Then it wasn't necessary to shut down and start up all over again?"

"No, you could have done the same thing by pulling your plugs, waiting a minute or so, and putting them back again."

"But what's the difference between opening the field switch with the plugs in and putting the plugs in with the field switch open?"

"None, ordinarily; but in this case there was. With the field switch closed, the armature will not build up any electromotive force, so that when you closed the circuit with the field "killed" and then opened the field switch, there was no pressure at the brushes. The armature was working up, though, when you shut down, and if you had let the machine stay in it would have broken through the lamp coil in a few moments more."

"But you said opening the switch first and then sticking the plugs would have been better."

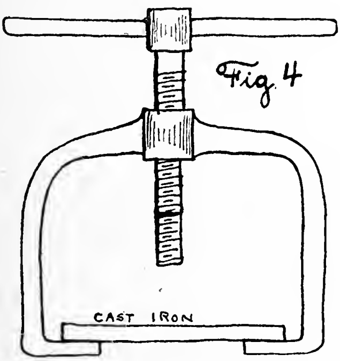


Fig. 4

"Yes. It would have broken down the coil at once without waiting so long."

"Why?"

"When you opened the switch with the circuit connected, the machine had no E. M. F. and had to work up through resistance. When you shut down and started up again with the field switch open and the circuit disconnected the dynamo worked up a pretty good E. M. F. in a moment or so, and when you stuck the plugs the shock broke down the fine wire coil and made a short circuit across the lamp, enabling the full current to pass and light the other lamps."

"I don't quite see it."

"Well, see here." Jones drew another rough sketch, like Fig. 4. "Now if you turn the handle of that screw long enough, it will break the cast iron plate, won't it?"

"Certainly."

"Well, if you hit the plate with a hammer it will take less time to break it, won't it?"

"A single blow would do it."

"Exactly. Now, the action of the screw toward and upon the cast iron plate is like that of the dynamo upon the lamp coil when you started the machine with the circuit connected."

"And the hammer is like the action of the machine when it is started first and then connected with the circuit?"

"Exactly."

"I see. But why did Sam (the trimmer) say I'd burn up his carbon holders?"

"You know the positive carbon is longer than the negative?"

"Yes, twice as long."

"Well, it is made so, because it burns out twice as fast. Now if you reverse the current through the lamps, the short carbon becomes positive and burns up entirely before the long carbon is one-third gone. This leaves nothing to carry the arc but the long carbon and the carbon holder of the burnt out short carbon, and the arc would soon melt the carbon holders."

"Why does the positive carbon burn quicker?"

"Because the current passes from it to the negative carbon, and carries a good deal of the positive carbon clear across and deposits it on the end of the negative carbon, so that the latter is constantly replenished and therefore takes longer to be consumed."

EXCESSIVE DROP IN THREE-WIRE CIRCUITS.

The next time Jones visited Millville he found the engineer in deep distress.

"I've had to speed up my engines," he explained, "because I couldn't get the voltage on the line up to 110, even with the rheostat handle clear over."

"Any grounds on the circuit?"

"No; there isn't anything wrong with the circuit, as far as I can see."

"Belts stretched much?"

"I've tightened them up all I can without heating the pulley bearings."

"There are no such things as 'pulley bearings.' "

"Well, you know what I mean."

"Yes; but don't get into using careless expressions. Say 'back bearings,' if you choose; that's bad enough."

Jones walked over to the switchboard and found the pilot lamps burning brightly and the instruments in normal condition, but noticed that the wires leading to one of the voltmeters had been rearranged.

"Why did you change those wires?"

"The thing got cranky and wouldn't read——"

"I never saw a voltmeter that could read. Mine simply indicates; it hasn't learned to read yet."

"Well, it wouldn't indicate, and I thought it might have got polarized or something, so I reversed the connections and it went all right."

"Oh, it did, eh? Now put them back as they were."

"But it won't re—indicate that way."

"Never mind; change them back again."

The engineer did so, and exclaimed triumphantly:

"I told you it wouldn't indicate."

"Yes, you did; but it's indicating as hard as it can."

The engineer gazed stupidly at the voltmeter and then at Jones.

"I don't see it move," he said.

"Look closer and you will see the needle jammed against the back-stop, trying to get away from the scale."

This was verified by a close inspection.

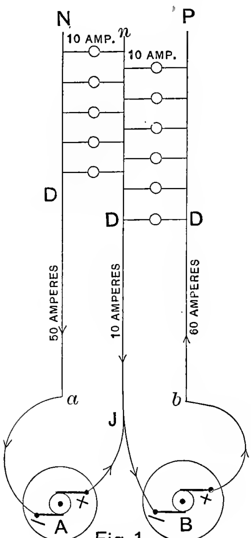


Fig. 1

Power, N.Y.

"Now, do you know what is wrong?"

"No."

"The voltmeter needle goes over the scale when you reverse the connections, doesn't it?"

"Yes."

"Then don't you see that the current is going through it in the wrong direction now?"

"I suppose so, but how can a continuous current change its direction?"

"It can't. But your dynamo can reverse and change its positive brush into negative, and it has done it."

The engineer glared resentfully at the offending dynamo and was speechless.

"When you shunt down to-night," said Jones, "adjust your engine governors like they were originally and reverse the main wires leading to this dynamo. Leave this voltmeter connected as it was at first, and you will find things all right at starting time."

"But——"

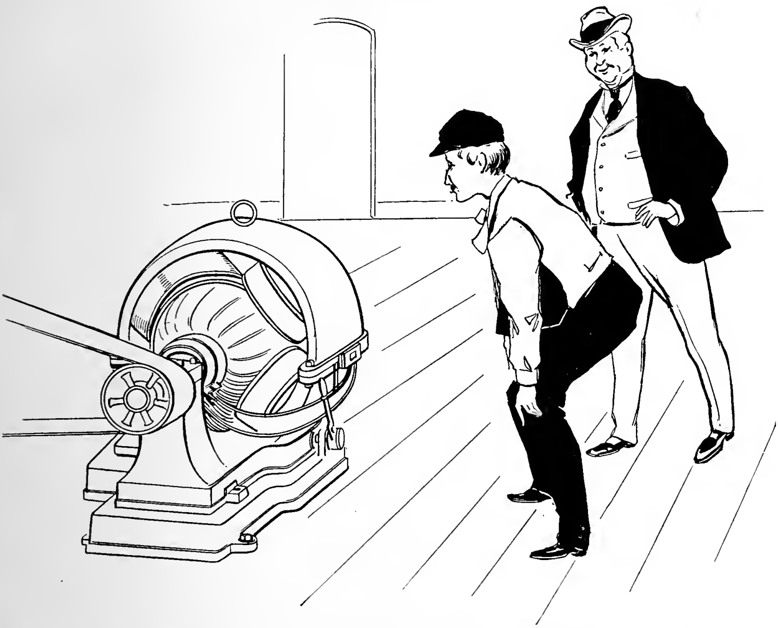
"I'll be back during the day to-morrow, and we can make a test beforehand, if you like."

The next afternoon Jones returned and found the governors and voltmeter connections restored to their original condition.

"While we are waiting for starting time to come," he said, "I'll show you what your trouble was," and he drew from his pocket a sheet with several diagrams printed on it. "I had these made for just such a case as yours. Fig. 1 is a diagram of a simple

three-wire system where there are no branches—just three straight line-wires with the load near one end and the dynamos at the other. Now, suppose each circle between the outside and neutral wires passes 10 ampères; there are six circles between the positive, *P*, and the neutral, *n*, and five between the neutral and the negative wire, *N*."

"So that the load from positive to neutral is 60 ampères and from negative to neutral is 50 ampères?"



The engineer glared resentfully at the offending dynamo.

"Exactly. Now, 50 ampères go straight across from the positive, *P*, to the negative, *N*; what becomes of the other 10 ampères that went from dynamo *B* out along the positive wire?"

"It comes back through the neutral wire."

"Right. You repeated Ohm's law to me once; can you write it in symbols?"

"Yes," and the engineer wrote:

$$C = \frac{E}{R}$$

"Now write it another way."

The engineer wrote:

$$R = \frac{E}{C}$$

"Yes; now the third form."

The engineer wrote $E = C \times R$.

"Good. Now look at Fig. 1. If the resistance of *P* from *b* to *D* is $\frac{1}{25}$ of an ohm, how many volts will be used in forcing 60 ampères through it?"

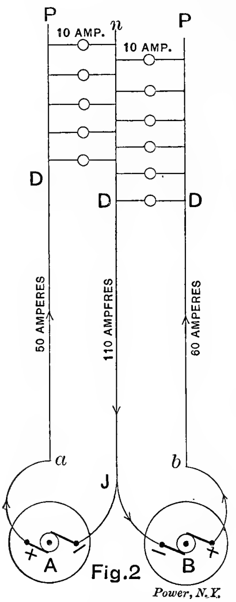


Fig. 2

"Sixty times $\frac{1}{25}$, or $2\frac{4}{10}$ volts."

"Right. And if *N* is the same resistance from *a* to *D*, how many volts are lost there?"

"Fifty times $\frac{1}{25}$, or 2 volts."

"Then it takes some E.M.F. to force the extra 10 ampères back through the neutral, *n*. Suppose the resistance of the neutral is $\frac{1}{10}$ ohm from *J* to *D*, how many volts are lost there?" $\frac{1}{10}$

"10 times $\frac{1}{25}$, or 1 volt."

"Now add up these losses between *a*, *J*, *b* and *D*."

The engineer did so, and said:

"$5\frac{4}{10}$ volts."

"Right. This is not the total loss, because the wiring from *a*, *J*, *b* to the dynamos is left out. We will neglect that, though. Now look at Fig. 2; see anything wrong about it?"

"The outside wires are both positive."

"Yes; so the neutral is not neutral at all, but has to serve as a negative return wire for both of the outside wires *P*, *P*. This is because dynamo *A* is reversed."

"Like mine was?"

"Just exactly. Now, assume the same resistances you had before and figure up the loss with 50 ampères in one outside, 60 in the other, and 110 ampères in the middle wire."

The engineer wrote $50 \times 1\text{-}25 = 2$ volts. $60 \times 1\text{-}25 = 2.4$ volts. $110 \times 1\text{-}10 = 11$ volts.

$$\begin{array}{r} 2 \\ 2\tfrac{4}{10} \\ 11 \\ \hline 15\tfrac{4}{10} \text{ volts.} \end{array}$$

"$15\frac{4}{10}$ volts total."

"Yes. Now your case was worse. Your neutral feeder was designed for only $\frac{1}{4}$ of the total load instead of $\frac{2}{5}$, because all of

"Your main feeder has a resistance of about $\frac{1}{24}$ ohm in each balance. What is your load on dynamo No. 1?"

"209 ampères is the maximum."

"And on No. 2?"

"200 ampères."

"Your main feeder has a resistance of about $\frac{1}{24}$ ohm in each outside wire and about $\frac{1}{6}$ ohm in the neutral. Figure the losses at 200 and 209 ampères."

"That means 9 ampères in the neutral, doesn't it?"

"Yes."

"Then the loss in the neutral is $9 \times \frac{1}{6} = 1\frac{1}{2}$ volts."

"Well?"

"The loss in No. 1 outside wire is 209 times $\frac{1}{24}$ and——"

"Add your loads and multiply by $\frac{1}{24}$."

"Then it's 409 times $\frac{1}{24}$. That is," after a period of scribbling, "17 volts."

"Add the neutral wire loss."

"That makes $18\frac{1}{2}$ volts."

"Therefore your dynamos must give $238\frac{1}{2}$ volts from *a* across to *b*."

"Yes, sir."

"Now, with No. 1 dynamo reversed the 209 ampères going out on one outside wire and the 200 going out on the other must come back through the neutral, making 409 ampères in that wire. Figure the loss." 1/6

"409 times $\frac{1}{18}$," pause and scribbling. "Good Lord, that can't be right."

"What is it?"

"68 volts and a fraction in the neutral."

"That's right. Now the loss in the outside wires must be added."

"That was 17 volts."

"Yes, when they were in series; but now they are practically in multiple. Take half the resistance and multiply by the full 409 ampères."

"$\frac{1}{48}$th of 409?"

"Yes."

"That's a little over $8\frac{1}{2}$ volts."

"Call it $8\frac{1}{2}$; that makes $76\frac{1}{2}$ volts loss; do you wonder that you had to speed up your engines to make that up?"

The engineer didn't wonder any longer in this direction, but he did in another.

"What made the darned thing reverse?" he asked.

"There is no telling. There are many things that could cause it. When the iron or steel of a dynamo magnet is extremely soft the machine is likely to excite in either direction for the first few times. A heavy blow will sometimes reduce the residual magnetism so as to make the machine uncertain in exciting."

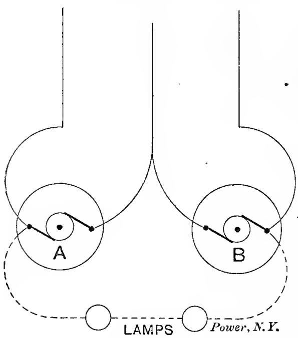


Fig.3

"How am I going to tell hereafter whether the dynamos are all right before I put on the load?"

"Connect two 120-volt lamps across from outside to outside of the dynamos (see Fig. 3), and if they light up both dynamos will be excited in the same direction. If they don't light up reverse the mains at the terminals of one dynamo."

"Suppose I reverse the wrong machine?"

"The voltmeters will both throw their needles away from the scale, and you will have to reverse their connections."

"Won't the change of polarity hurt anything on the circuit?"

"Not unless you have arc lamps on your incandescent circuit. Then you must shut down, straighten back the dynamo mains you had reversed, and reverse those of the other dynamo."

CARELESS PARALLELING OF DYNAMOS.

The Millville factory and shop owners had realized the great advantages of electric motors to such a degree that the little central station had accumulated a motor day load of considerable magnitude, necessitating the installation of another dynamo in

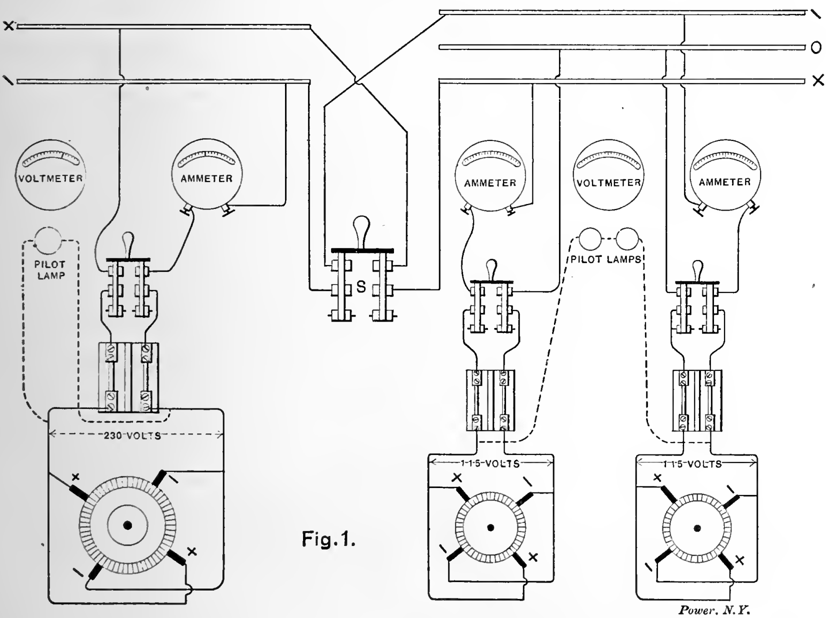


Fig. 1.

order to avoid working the two 500 lighters day and night. Accordingly, a 230-volt, 100-kilowatt generator had been put in and a separate motor circuit established. Then the lamp load gradually increased until, for an hour or so early in the evening, the two 115-volt machines were slightly overloaded. In order to relieve this overload it was the custom to couple the motor circuit,

which was not fully loaded, with the outside legs of the three-wire system, operating the whole as one system, as shown diagrammatically in Fig. 1. The voltmeters were provided with voltmeter switches (not shown) whereby each could be connected with the pressure-wires, the bus-bars or the dynamo brushes. These connections are omitted for clearness.

The 230-volt dynamo and its circuit were operated all day, and at dusk the three-wire system was started up and coupled, by means of the switch *S*, to the 230-volt system. The manipulation of this switch and the adjustment of the dynamos was entrusted to Sam, the trimmer, the engineer standing by the throttle until everything was working smoothly. Repeated success in "bunching" the circuits developed an overconfidence and carelessness in Sam which one evening caused the addition of several gray hairs to the engineer's stock and almost wrecked the dynamos.

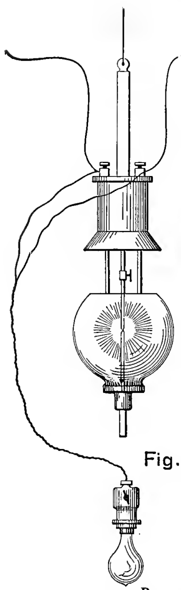


Fig.2.

Power, N.Y.

On the occasion referred to the engineer had brought the two smaller machines up to speed and was standing at the throttle of their engine when Sam closed the switch *S* connecting the two circuits. There was an ominous screech that chilled the engineer's blood, a sputtering and flashing at all of the brushes, a yell of "Stop her! stop her!" from Sam, and two reports like musket shots as the fuses of the 115-volt dynamos blew, followed instantly by those of the larger machines—all of these occurrences being so nearly simultaneous that there was no opportunity to do anything but gasp.

The engineer felt weak in the knee-joints as he rushed over to the switchboard. The machines were all running as peacefully as lambs, but the circuits were of course dead, the fuses being gone.

"What in h—l did you do?" demanded the engineer.

Sam's self-assertiveness bristled.

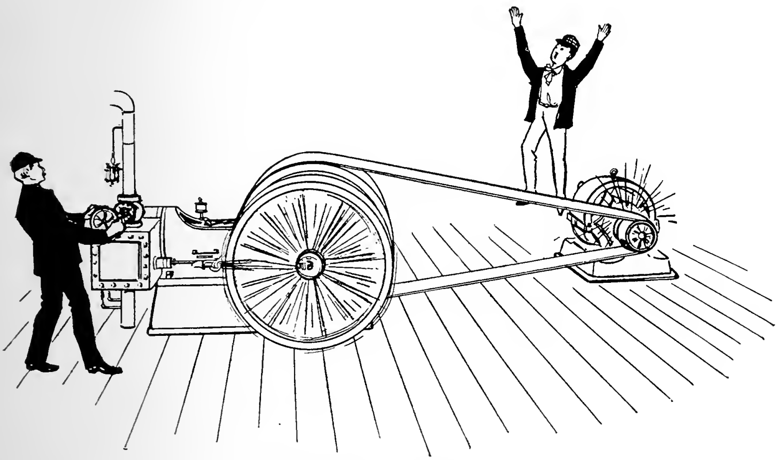
"Didn't do nothin' but shut the switch," he snapped out.

"You must have done something wrong; they never cut up that way before."

"Well, I guess I know how to bunch 'em."

The engineer said no more, but, profiting by his last experience, began a minute examination of the switchboard. Nothing seemed wrong except the melted fuses; both of the pilot lamps across the terminals of the 115-volt dynamos were burning brightly, and the 230-volt pilot lamp on the large machine was also burning, though not so brightly as the other two. Then the engineer switched his voltmeter over to the terminals of the big machine; it indicated 228. He next switched it to the pilot lamps of the two small machines; it indicated 240!

"It's about time you knew better than to switch 240 volts on to 228," he remarked caustically.



"Stop her! Stop her!"

"I didn't," said Sam, determined to evade all responsibility. "Them little machines have raised since they warmed up."

"Hello, here; what's up?" and Jones' cherry face appeared in the doorway.

The engineer recited hastily the occurrences.

"All right," said Jones; "shut down your engines, open all your switches, and put in fresh fuses."

While the fuses were being restored, Jones made a close examination of the dynamos by the aid of a 45-volt incandescent lamp connected in shunt to one of the station arc lamps (see Fig. 2). The commutators were blackened and burned a little, but sandpaper soon corrected this and in a very few minutes all of the machines and circuits were in operation again.

"Now, tell me more about it," said Jones.

"There isn't anything more to tell," said the engineer. "I told you exactly what happened."

"Who worked the switchboard?"

"Sam."

"Did you examine the board afterwards?"

"Yes; nothing was wrong except that the voltmeter showed 240 on the small machines and 228 on the big one."

Jones grinned and then looked savage.

"Where's that d—d fool?"

"Sam? He's gone. He said the little machines raised their voltage after they warmed up."

"He did, did he? Well, you tell him for me that he's an ass." Just then Sam came in, with his arrogance all restored. "Hi, come here," called Jones.

Sam came, smiling.

"So the little machines raise their voltage when they warm up, do they?"

Sam's smile evaporated.

"Y-yes, sir; I mean—no—yes——"

"I suppose so. When you get time, read some electrical primer, and you'll find that wire increases its resistance when it heats, so that a field magnet coil has less current in it warm than cold, and the voltage of the machine is lower when the machine is warm than when it's cold."

"Yes, sir; of course, but——"

"Shut up. Why didn't you use the voltmeter before you threw the small machines in circuit?"

"The pilot lamps looked all right, sir," very meekly.

"Oh, they did? And do you think you'd look all right if I told the chairman you nearly wrecked the station because you were too lazy to use the voltmeter switch?"

"Please sir——"

"No, I'm not going to tell on you this time, but hereafter you'd better follow your instructions and wait for your judgment to ripen."

Sam vanished in the night air with not a trace of swagger.

The engineer turned to Jones with an air of interrogation.

"Perfectly simple," said Jones. "Here is what you had just

before the switch was closed between the circuits," and he made the sketch shown by Fig. 3. "Now when the switch was closed, the connections shown by the dotted lines *a* and *b* were made."

"Yes."

"Then the difference of 12 volts between the two circuits forced current through the big armature and the series field coil *backwards*, and the big machine was driven as a motor."

"Backwards?"

"No, in the same direction, because the shunt field magnetized

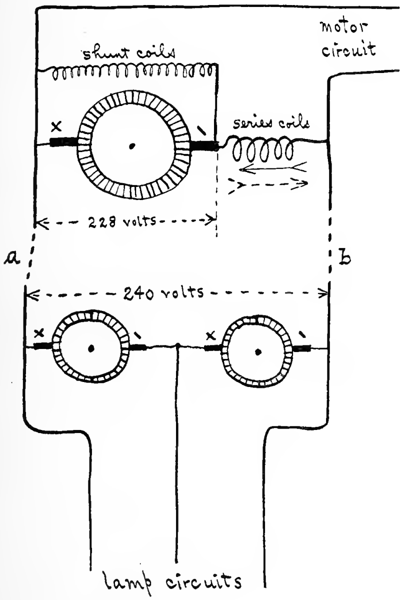


FIG. 3.

in the same direction as before. The current in the series field was reversed though, as indicated by the dotted arrow, and this weakened the field magnet."

"What effect did that have?"

"Increased the speed of the machine."

"Does a motor run faster with a weakened field?"

"Yes; up to the point where the field is too weak to pull over the armature."

"Why?"

"Because the back E.M.F. of a motor armature must equal the E.M.F. applied at the brushes, minus the volts lost in the armature, and its value depends upon speed and field magnetism If the field weakens, the motor speeds up to maintain its back E.M.F. at the proper point."

"Then why should there have been any trouble? Why didn't the big dynamo simply speed up to make up for the weakened field?"

"It did try to, but it had to drag the engine with it; besides, it couldn't change its speed in an instant, even without the engine, and before it reached the high speed necessary to make its back E.M.F. good the fuses blew."

The engineer scratched his head in a puzzled fashion.

"I don't exactly see why the fuses should have blown."

"You see that there was an excess of 12 volts between the two circuits, don't you?"

"Yes."

"Well, ignore the outdoor circuits and consider the dynamos connected together."

"Well?"

"The resistance of the big armature and the series coil together is about $\frac{18}{1000}$ ohm; now when the switch was closed the E.M.F. of 228 volts from the big armature opposed 228 volts of the 240 generated by the two small armatures, leaving 12 volts opposed by nothing but wire resistance."

"The $\frac{18}{1000}$ of an ohm?"

"That added to the resistance of the small armatures and the intermediate connections. These amounted to approximately $\frac{25}{1000}$ or $\frac{1}{40}$ ohm, so the total resistance through the three armatures, etc., was——"

"Forty-three thousands of an ohm."

"Yes. Now see how much current 12 volts can drive through forty-three—make it fifty thousandths for heating and good measure; fifty thousandths or one twentieth of an ohm."

The engineer scribbled on the back of his memorandum book and then looked up in surprise.

"That can't be true," he said; "it isn't enough to hurt anything."

Jones smiled. "How much was the first rush?"

The engineer showed him these figures:

```
.05) 12.00 (240
     10
     --
      20
      20
      --
```

"Two hundred and forty ampères?"

"That's what it figures out."

"Precisely; but that state of affairs lasted less than one second. Then your series field coils had neutralized enough of the exciting power of the shunt coils to cut down the total field about 40 per cent, reducing the E.M.F. of the big armature to 60 per cent of its first value—what is 60 per cent of 228?"

"One thirty-six and eight-tenths," after some scribbling.

"Call it 137 for even figures; that leaves how much unbalanced voltage?"

"137 from 240—103 volts."

"Now see how much current 103 volts will force through $\frac{5}{100}$ ohm?"

The engineer divided 103 by 0.05 and said:

"Nearly 2,100 ampères."

"Yes; but it is probable that the fuses blew before it got anywhere near that, or you wouldn't have any dynamo left."

The engineer seemed absorbed.

"What's worrying you now?"

"I was only wondering where it would stop. As the reversed current increases, the series coils get stronger in the wrong direction and weaken the field more and more, and——"

"Yes, but your armature speeds up and increases the back E.M.F., so that the current doesn't go up by jumps, but with a sort of swoop. If the armature had no weight, so that it could change its speed the instant the field weakened, there would be no increase in the current, but the speed would increase until the back E.M.F. equalized the incoming E.M.F. (minus the 'drop') under the weakened field."

"What was the awful screeching?"

"The belts all slipping around the pulleys, due to the sudden overload on all the machines."

"Why haven't we had this trouble before?"

"Because Sam tried the E.M.F. of the machines with the voltmeter before he threw them together. There isn't the slightest danger, if one uses the voltmeter and a little horse sense. The safest plan is to let the small dynamos lack a volt or two of the E.M.F. of the compound-wound machine when you couple them. Then the big dynamo will take a little more than its own load and help the others out."

A "DEAD" DYNAMO AND HOT FIELD COILS.

Several months later Jones, on one of his frequent visits to the Millville Station, found the engineer sitting on the floor near one of the small dynamos, his face and hands bearing grimy evidence of unusual toil, and a despondent air being obtrusively manifest.

"Well, tell me all about it," he said, appropriating a small tool-chest for a seat.

"She's as dead as a door-nail," said the engineer, indicating by a disgustful wave of a monkey wrench the near dynamo.

"Since when?"

"Stopped generating an hour or so before shutting down time this morning."

"Were you here?"

"No; the boy called me."

"What did you do?"

"Started up the 220-volt machine and put it across the outside legs and then put a bank of lamps between the neutral and the light load side to balance."

Jones arose and whacked the engineer on the back enthusiastically. "Good boy," he said. "Now tell me about the lame duck."

"Break in the field circuit somewhere."

"How do you know?"

The engineer looked injured.

"Why, I tested to see, of course," he replied.

"How?"

"Connected the field circuit with the good machine to charge it, but it wouldn't give a spark. You see, I thought it had lost its magnetism."

"And you could get no current through the field circuit?"

"Not a bit."

"Had any trouble with it lately?"

"None to speak of. I noticed that three of the coils ran warmer than the fourth one for a day or so, but not warm enough to hurt."

"Rheostat heat up unusually?"

"I didn't notice that."

"Get me enough lamp-cord to reach from the dynamo to the switchboard, with six feet to spare, and put a lamp socket on one end of it and an attachment plug on the other. And bring a pair of those extra plugs from the arc switchboard."

This was done, and Jones proceeded to cut one conductor of the lamp-cord about four feet from the lamp socket and untwist the conductors for a couple of feet on each side of the break. Then he fastened the ends of the severed conductor to the switchboard plugs, transferred one of the pilot lamps of the 220-volt machine to its socket, and screwed the attachment plug into the pilot lamp socket. The result was an arrangement like that shown in Fig. 1. Obviously, a connection between the plugs would cause the lamps to light up.

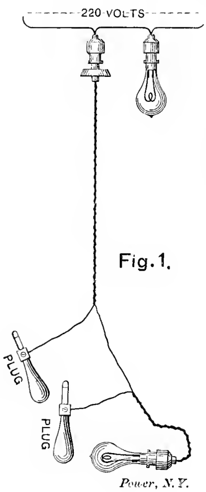


Fig. 1.

"Now disconnect your rheostat wires."

The engineer did so.

"Hold them against these plugs."

The engineer obeyed, and the lamps remained dark

"Open in the rheostat circuit somewhere. Why didn't you try that before?"

The engineer simply looked sheepish.

Jones went to the switchboard and applied the plugs to the terminals of the rheostat, but no light resulted.

"Turn the handle," he said.

The engineer turned the rheostat arm, and when the contact finger touched the third button from the "all-out" position the lamps lighted. The engineer heaved a sigh of relief.

"Don't be in a hurry; you're not out of the woods yet," said Jones grimly.

"It's easy enough to 'bridge over' that break," said the engineer.

"Yes, quite simple; but that's only the beginning. There's a short circuit in one of your field coils."

The engineer stared in amazement.

"How do you know that?" he asked.

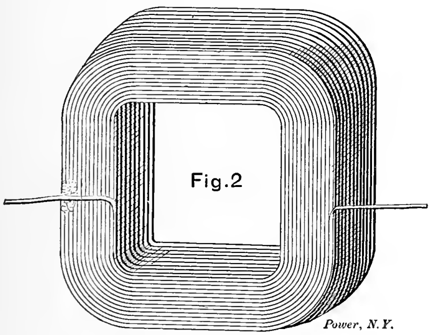
Jones grinned. "That coil that ran so beautifully cool is either cut out entirely or has a short circuit that cuts out most of it."

"Then the other three ran hot because they were doing all the work?"

Jones nodded and walked over to the affected dynamo.

"Which coil ran cool?" he asked.

The engineer indicated the left-hand upper coil, which Jones



proceeded to uncouple from its mates. Then he attached to the hand plugs of his testing arrangement (Fig. 1) the ends of a length of flexible cord leading to the low scale terminals of a portable voltmeter which he habitually carried, and placed the voltmeter on the floor.

"Take the readings," he said to the engineer.

Then he applied the plugs to the terminals of the suspected coil. "What is it?" he asked.

"Nothing," replied the engineer.

Jones applied the plugs to the terminals of another field coil. "Now," he said.

"One and four-tenths volts."

"Now," repeated Jones, touching the terminals of a third coil with his plugs.

"One and three-tenths."

"Once more," and he touched the fourth coil's ends.

"One and four-tenths."

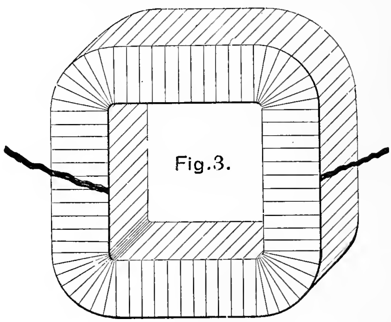
"Pretty close results," commented Jones. "That cold-blooded coil is entirely short-circuited; the other three are all right."

"What's to be done?"

"Lift off the upper half of the field magnet and take out the coil."

With the aid of a portable, or rather movable, gallows crane this was soon accomplished, and Jones quickly stripped the insulation off the sides of the coil whence the terminals issued.

"Thought so," he muttered, as he exposed the end of the coil across which the starting end was led outward. A charred spot



Power, N.Y.

at the outer edge (*A*, in Fig. 2) showed the location of the trouble.

"What made it burn there?" asked the engineer.

"The vibration of the machine caused the terminal wire to rub through the insulation, and the current simply went across from the starting end to the outside turn instead of going through the coil."

Jones pried the end layers apart gently with a dull-pointed screwdriver and stuck a sliver of mica between each pair of layers. Then he varnished the end face of the coil heavily with shellac, let it harden, and then taped the coil, but left the terminal outside and taped it separately, so that the coil looked like Fig. 3 when it was ready to go back in place.

"Why didn't they fix the end that way at the factory?" asked the engineer.

"They always do now. That coil must have been taken from a

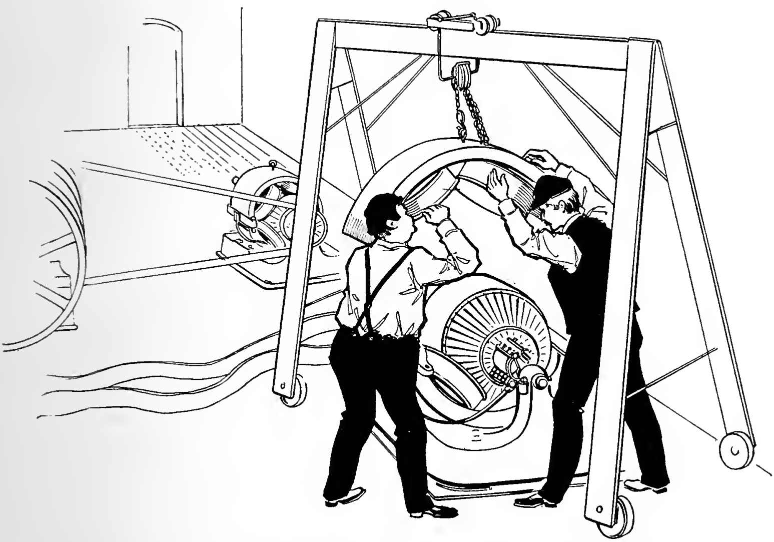
lot made up before they changed the arrangement of the inner terminal. I'll have a new one sent to replace it."

When the coil had been put back in place Jones applied the hand plugs of his improvised testing outfit to the terminals, and the engineer read the voltmeter indication.

"One and nearly five-tenths."

Jones vented his satisfaction in a chuckle. "Let's try 'em all around again," he said, applying the plugs to the next coil. "Now."

"One and five-tenths."



With the aid of a portable crane the top half was lifted off.

"Again."

"One and four-and-a-half."

"Last coil."

"One and five."

"Good as gold," said Jones. "Let her down again."

The engineer lowered the suspended half of the field magnet, Jones guiding it into place, and the machine was soon running as placidly as ever.

"Why were the last voltmeter readings higher than the first ones?" asked the engineer.

"Because your load on the motor circuit happened to be heavier and the E.M.F. at the switchboard was higher."

"Well, what did those readings indicate, anyhow?"

"Only the comparative condition of the coils. As long as the voltmeter indications were the same, or practically the same, it was safe to assume that the coils were of equal resistance. It was immaterial what the voltmeter indicated so long as it indicated something, and the same something for each coil."

The engineer did not wholly take in this reasoning, and his face showed it. Whereupon Jones relapsed into diagrams, drawing Fig. 4.

"That is what we had, isn't it?" he asked.

The engineer admitted that it was.

"Now, suppose that the voltage across the bus-bars is 230, and that a current of $\frac{1}{2}$ ampère passes through the circuit. If the coil

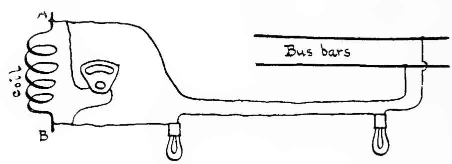


FIG. 4.

has a resistance of 3 ohms, what will be the voltage at its terminals?"

The engineer wrote

$E = C \times R$. If $C = \frac{1}{2}$ and $R = 3$, then $E = \frac{1}{2} \times 3$, or $1\frac{1}{2}$.

"One and a half volts," he answered.

"Now, suppose the coil had practically no resistance——"

"But that isn't possible," interrupted the engineer.

"No; but if the ends were connected together by a heavy short-circuit, the resistance from *A* to *B* would be inappreciable, and in that case——"

"The voltmeter would be short-circuited and wouldn't indicate."

"Precisely so. Isn't that what we found?"

"Yes. Suppose only a part of the coil were cut out, what would happen?"

"Figure it for yourself. With $\frac{1}{2}$ ampère you said the 'drop' in

the coil was 1½ volts; that leaves 228½ for the two lamps, cord, and connections, which means a resistance of what?"

"Two hundred and twenty-eight and a half divided by one-half; four hundred and fifty-seven ohms."

"Now, if one-third of the coil were cut out by a good solid short-circuit, the resistance left would be——"

"Two ohms."

"Add this to the circuit resistance of 457."

"Four hundred and fifty-nine ohms total."

"And the current flowing, under 230 volts?"

"Two hundred and thirty divided by four hundred and fifty-seven"—pausing to scribble—"a trifle over half an ampère."

"And the drop in the damaged coil?"

"About a volt."

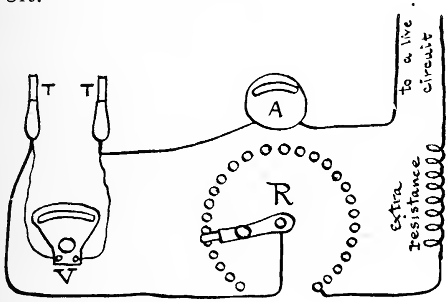


FIG. 5.

"Practically two-thirds of the drop in a good coil, showing that about one-third of the coil is cut out."

"But isn't there some way of getting at it without so much figuring?"

"Yes. If you wanted to find the actual resistance of a coil and had no Wheatstone bridge, you could rig up a testing outfit this way," drawing Fig. 5. "The extra resistance may be a coil of wire or a 110-volt incandescent lamp of 32 candle-power or over. *R* is a dynamo regulating rheostat—as small a one as you can get; *A* is the ammeter off your arc light switchboard, and *V* is a voltmeter with a low and a high scale."

"Why are two resistances necessary?"

"The extra one may not be. If *R* is sufficient to cut down the current to one ampère when the testing terminals *T* and *T* are

together, no extra resistance will be needed. If not, then enough extra resistance must be put in to bring the current down to an ampère when the finger of *R* is on the last button, or somewhere near it."

"How do you test with that arrangement?"

"Connect the terminals, *T*, *T*, with the coil, or whatever you wish to test. Adjust the rheostat until the ammeter indicates exactly one ampère; then the voltmeter will indicate the resistance in ohms of whatever *T* and *T* are touching. These terminals should be clamps if the object tested is of low resistance, so that the resistance at the contacts will be inappreciable."

Jones was half way to the door, leaving the engineer studying the sketch, before the latter realized his departure.

"Hey, there," he cried; "wait a minute."

Jones paused and turned about.

"When one coil was cut out, why didn't the E.M.F. of the dynamo drop 25 per cent?"

"Because the resistance of the three coils was one-fourth less than that of all four, and the current was therefore one-third greater; three coils passing 12 ampères are equal to four coils passing 9 ampères, if the coils are alike."

"Oh, yes. But why didn't the dynamo spark like fury with an unbalanced field?"

"Because the armature is wound so that each path, from brush to brush, passes under all four poles instead of only one, and all four paths gave the same E.M.F. Good-night."

A "BREAKING" ARC CIRCUIT — SIMPLE GROUND DETECTOR.

"I'm sure I can't imagine what the devil ails the confounded thing," admitted the engineer, with a sigh of vexation.

"Mebbe the old machine's begun to do like them incandescent dynamos—slack down when she gits warmed up," hazarded Sam.

The engineer shook his head dubiously. "She wouldn't have run all right up to now and then take on such capers," he said.

It was the arc light dynamo that worried the men.

"Did you look over all your lamps last night?" asked the engineer.

"Every last one," averred Sam stoutly, "and they was all as white as snow and fine as silk."

"Every one—every single lamp?" persisted the engineer.

"Yes; every one—leastways every one in reach," with a sudden revival of memory. "You know there's two upstairs in old man Stringer's place that I trim just before he shuts up, and I can't see 'em from outside."

The engineer looked bored and disgusted.

"And you've spent a week looking for bad lamps and had me worried half to death, and never thought of those lamps," he exclaimed. "Bring 'em in right away."

The lamps were brought in forthwith and others put in their places, and that night the circuit worked worse, if possible, than before. The engineer was in despair the next morning.

Later in the day he became suddenly possessed of an idea, and when no one was around he took down *one of the station lamps* which had been recently hung to illuminate an improvised testing rack and work-bench for arc lamps. That night the circuit behaved in an orderly and dignified manner, to the intense relief of

the engineer and the great mystification of Sam, who never learned the secret of the sudden remedy.

Jones happened along in the course of a few days and the engineer promptly carried him off to a remote corner and unfolded his tale of distress.

"What did the circuit do?" asked Jones.

"Burned all right for a time, but got weaker and weaker until about 9 o'clock, when it 'broke' and then started up smoothly again."

"Burn smooth the rest of the night?"

"No; it broke that way two or three times during the night."

"Dynamo fully loaded?"

"Yes."

"Regulator 'clear over' at full load?"

"Yes; but it has a margin after the private lamps are cut out."

"Then the circuit didn't weaken previous to the breaks that followed the first one."

"How do you know that?"

"Because the reason it grew weak before the first break was that the regulator couldn't strengthen the field of the dynamo any more, the maximum being reached at that time."

"Well?"

"Well, the carbon rod of your defective lamp hung up and as the carbons burned away the resistance of the arc increased. The effect was the same as cutting two or three lamps in circuit, and as the dynamo was giving its maximum voltage and couldn't give any more, the increased resistance cut down the current in the circuit, but it couldn't have cut it down very much."

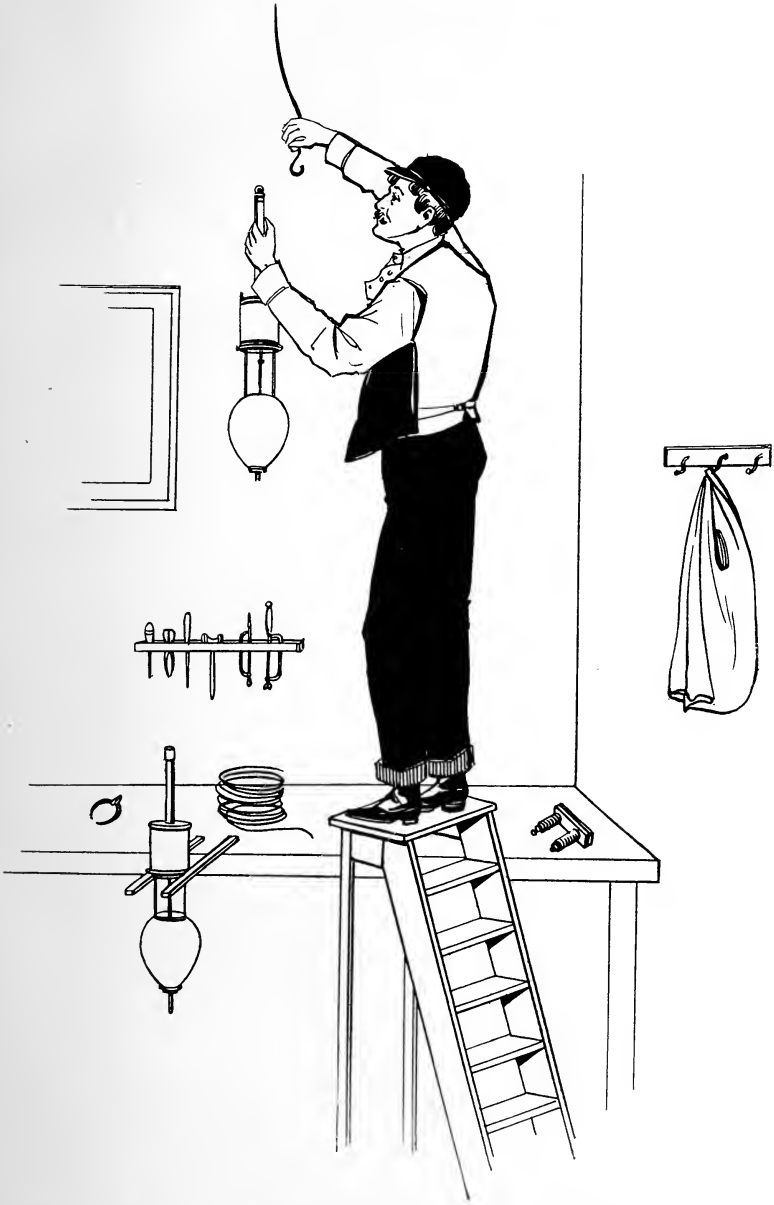
"It dropped from 9.6 to 8 ampères."

"Quite probable. And after the private lamps were cut out it didn't drop at all until the circuit actually broke, because you had some reserve voltage and the regulator took care of the lengthening arc just as it would of an increase in the number of lamps."

"Why did the lamp hang up?"

"Something wrong with the feed. Let's look at it."

The engineer led the way to where the defective lamp was and Jones put it on the bench, removed the box casing and proceeded to examine the mechanism.



When no one was around he took down one of the station lamps.

"Why, the lamp hasn't any automatic cut-out in it," he exclaimed. "Who took it out?"

The engineer colored and looked abashed. "I took it out to replace a damaged cut-out in a street lamp," he explained.

"That's all right, but you shouldn't allow this lamp in circuit anywhere in that condition."

"I know it, but I thought being right here in the station we would notice anything wrong with it and cut it out."

Jones grunted derisively and proceeded with his examination of the lamp.

"Shunt coil disconnected and arc-strike too short," he announced. "You must have jabbed the shunt coil terminal when you took out the cut-out."

The engineer was speechless with mortification. Jones grinned reassuringly.

"Never mind," he said, with his usual cheery air restored, "everybody makes blunders, and you'll know better next time," which comforted the engineer somewhat.

"What effect did the adjustment for striking a short arc have?" he asked.

"Rather a beneficial one as it happened. The lamp struck a very short arc so that it took longer for the carbons to burn away until the arc broke than if the regular size arc had been struck."

"And the reason the carbon rod hung up was that the shunt coil was disconnected and could not work the feed?"

"Precisely so. The series coil simply lifted the rod with a bang and held it there until the carbons burned away and opened the circuit."

"You see," said the engineer apologetically, "I don't stay around after nine o'clock much, and the boy is around the dynamos and never comes over to this corner.

"All the more reason for having a good lamp here," said Jones, dryly. "You can put it down as a safe rule that no apparatus is too good for station use, so far as the vital working parts are concerned. You can use lamps and other things in the station that don't present a good enough appearance for a customer, but the 'works' should be in apple-pie order. The practice of using damaged switches, blackened incandescent lamps, defective arc lamps," with a sly twinkle, "and such things, around any plant

is a most short-sighted one. Another thing—whenever you have any circuit trouble *always* begin to look for it in the station."

This little homily delivered, Jones changed the subject.

"How are your circuits; all fairly loaded?"

"The 110-volt circuits have considerable margin since I changed some of the motors to 220 volts."

"Better displace five of your private arc lamps on the arc circuit with five constant-potential arc lamps on the 110-volt circuits. Then your arc dynamo will have a reserve E.M.F. and the regulator can take care of long arcs or other demands for more voltage."

The engineer signified his acquiescence and fidgeted around uneasily for a few moments.

"Well, what's troubling you now?" asked Jones, amused by his sheepish expression of countenance.

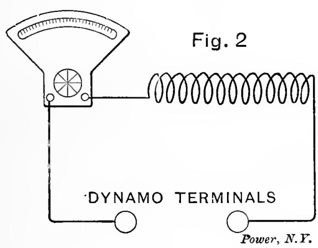


FIG. 1.

"I want to make a ground detector and tester for the arc circuit."

"That's simple. Get twenty-five 100-volt incandescent lamps, 8 candle-power each, a rheostat face with twenty-four contact buttons, a double-pole knife-switch for high potential, and a coil of fine German silver wire of high enough resistance so that when your 600-volt portable voltmeter is connected in series with this coil across your dynamo terminals like this" (Fig. 1), "the voltmeter needle will not go beyond the scale. Then arrange your things this way," drawing a diagram like Fig. 2.

"How do you use it?" asked the engineer, a little doubtfully.

"Close the switch and carry your rheostat handle from one extreme to the other. If the voltmeter needle doesn't move at all, there is no ground. If it indicates at any part of the rheostat

travel, move the handle until you reach a button where the voltmeter needle shows the lowest indication—zero, if you can get it so low. Then the ground on your circuit will occupy the same position with relation to the arc lamps that your rheostat finger does to the incandescent lamps."

The engineer seemed a little dazed.

"See here; suppose you have fifty arc lamps in circuit and twenty-five incandescents in your detector, then——"

"I see," broke in the engineer, "each incandescent lamp would represent two arcs and the position of the rheostat finger in the string of incandescents would correspond with the position of the ground on the circuit of arcs."

"Exactly so. If the voltmeter indicated zero (or minimum)

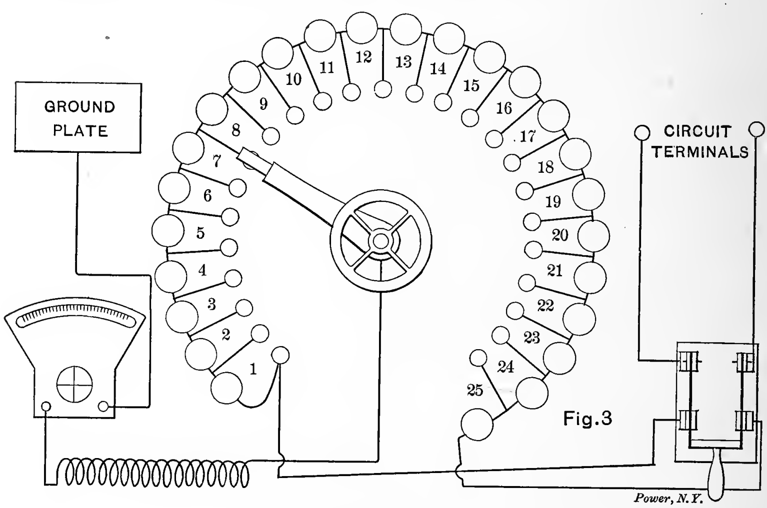


FIG. 2.

when the rheostat finger was between lamps Nos. 7 and 8, counting from left to right, the ground on the line will be found between the 14th and the 16th arc lamps, counting from the left-hand end of the circuit."

"Suppose there are two grounds on the circuit?"

"Then all the lamps between the two grounds will burn either very weak or not at all, and the ground detector will act as though there were just one ground midway between the two that really exist."

"Then if there were two grounds, one at lamp No. 27 and one at No. 33, the ground detector would indicate one ground near lamp No. 30?"

"Exactly. And your lamps from No. 27 to No. 30 would either be out or very red and weak."

ANOTHER CASE OF "DEAD" DYNAMO. LOW VOLTAGE.

"I swear I've a good mind to throw the cussed machine in the canal," sputtered the engineer, wrathfully glaring at the 250-volt dynamo. The dynamo manifested no concern as to its impending doom, but lay there innocently, "dead to the world" in general and to its own circuit in particular.

It's the second time I've had trouble with it inside of three months," continued the soliloquizer, " and I'm worn out."

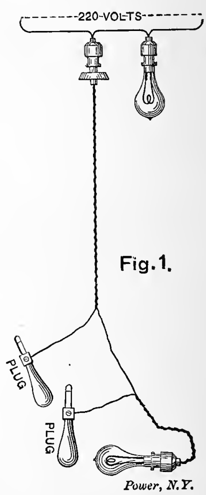


Fig. 1.

Sam shifted to the other leg and looked sympathetic, but vouchsafed no audible condolence.

"Go telephone Jones to come over right away. He's at Centerville to-day."

Sam went, and Jones appeared within an hour. The engineer's temper had effervesced and he presented the case more calmly.

"Won't generate?" said Jones. "What did you find?"

"Nothing; that's what's worrying me."

"Field circuit test up closed?"

"Yes; rheostat and all. And there is no ground."

Jones scratched his head and looked thoughtfully at the dynamo.

"Sure about the ground?"

The engineer didn't reply, but stepped over to the dynamo and applied the terminals of his testing arrangement (Fig. 1) to one field terminal and the frame of the dynamo; the lamps remained dark.

"Try the field circuit again," said Jones.

The engineer touched the shunt field terminals (the brushes were raised from the commutator) with the plugs and the lamps glowed, but were dull red.

"Poor circuit," said Jones. "Looks as if there was a bad connection somewhere."

As he spoke the lamps went out, and the engineer looked blankly at the dynamo and then at Jones. The latter worthy merely grinned with an irritating degree of cheerfulness.

"What in the ——" began the engineer, still pressing his field plugs against the field terminals.

"Don't. The fish won't bite," said Jones. "You have a broken connection somewhere; test the field coils separately."

The engineer removed the tape from the connecting clamps between the field coils and applied one test plug to the upper field

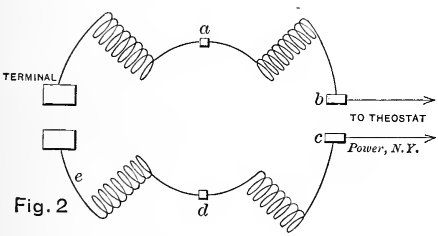


Fig. 2

terminal and the other to the clamp on the other side of the nearest coil (*a*, in Fig. 2). The lamps burned brightly. Then the rheostat terminals, *b*, *c*, were touched with the plug, with the same result. So also as to *d*, but when the plug was applied to the lower field terminal the lamps were dark.

"Broken between the last clamp *(d)* and the terminal block," said Jones. "Look for a short bend in your connecting wires."

Sure enough, further investigation revealed that the lead, *e*, which was a small stranded cable, was broken inside the insulation at a point where it was bent at a sharp angle to turn upward to the terminal block. The ends presented a peculiar appearance, being of a dull brownish-yellow and rounded.

"Why do the cable ends look that way?" asked the engineer.

"Burnt," said Jones. "Part of 'em broke and the others burned in two."

"Why didn't the machine excite when the circuit tested up closed?"

"Because there was probably the merest contact between the ends of one broken strand, and this was of such high resistance that sufficient current to excite couldn't get through."

"But enough current passed to light the lamps," said the engineer.

"Yes, to a measly dull red. About a third of an ampère passed. If you had raised the brushes and thrown the field in circuit, the remaining contact inside the insulation would have burned away instantly, instead of sizzling itself in two when your test lamps were in series with it."

"What broke the strands of the cable first?"

"Yanking it up and down when the boy wiped off the machine. Now, I've got to hurry back to Centerville. Better go over all of your field connections and see that there aren't any more in that fix. And make the boy unclamp the heavy terminals and clean the surfaces; they look dirty. Telephone me if you have any more trouble."

Jones' final suggestion proved to be well advised, even if superfluous. Immediately after supper he was called to the telephone to talk to the engineer.

"Hello; what's the row?"

"That 250-volt dynamo won't hold up its voltage," said the engineer. "I've had to keep the boy at the rheostat to move it up every time the load increases."

"E.M.F. drops when the load increases, does it?"

"Yes; and drops a great deal. We've passed the 'peak' of the load all right, but the dynamo didn't take its share with the rheostat all out."

"E.M.F. come up again when the load lightened?"

"Yes; the load is light now, and we have to hold her down with the rheostat?"

"Spark at the brushes under heavy load?"

"Yes, like the devil."

"I never saw the devil spark at the brushes. As soon as the load falls to where the other dynamos can take it all, cut out your bad-working machine and reverse its series field connections at the terminal blocks. Then put it in circuit again and try it."

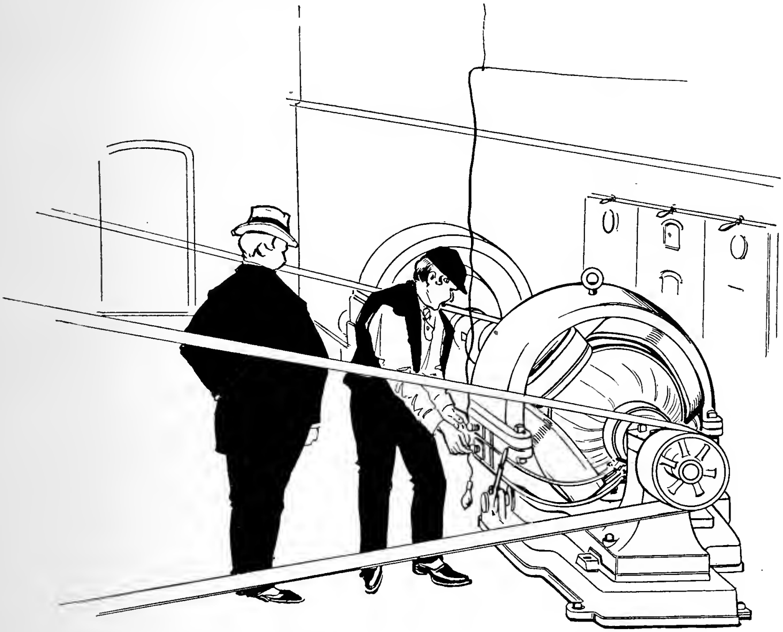
In the course of two hours Jones was called up again.

"Works like a lamb, now," said the engineer.

"With the series field coils reversed?" asked Jones.

"Yes."

"Then your boy must have swapped over the connections when he cleaned the terminals to-day."



The engineer touched the shunt field terminals with the plugs.

"So that the series coils were connected backward and weakened the field as the load increased?"

"Yes."

Jones heard a muffled imprecation in the receiver.

"That all?" he asked.

"Yes—no. What caused the sparking?"

"The weakness of the field. Good-night."

CARELESS MOTORMEN — AN EQUALIZER TROUBLE.

Millville had just assumed the glory of an electric railway—a "belt line" which bounded the heart of the town and had an extension from the upper end of town through an outlying factory district to the "fair grounds."

While the railway was owned by private capital an arrangement had been made for current to be supplied from the town power house presided over by our friend the engineer, and the necessary generators and engines had been duly installed there —two direct-connected units of 100 kilowatts each.

The superintendent, electrician and engineer-in-chief of the railway plant, according to Sam's homely judgment, was "a ornery dum critter, so sweet on hisself he's 'bout to spile." This official occasionally annoyed the engineer by officiousness during the latter's absence.

On a gala day soon after the railway started up, when the travel out toward the fair grounds was unusually heavy, the engineer overheard the following colloquy upon returning from dinner:

"I ain't goin' to do it less'n the boss say so."

"But I tell you it's necessary, to keep the cars going."

"Can't he'p it; they'll hafter wriggle 'long best they kin till——"

Bang! A circuit-breaker went out.

"There, now, don't you——"

"What's the trouble, Mr. Harvey?" asked the engineer, stepping into view.

"Well, you see," began the "ornery dum critter," somewhat apologetically, "I only——"

"He on'y wanted me to tie up the circuit-breaker," broke in the engineer's assistant bluntly, "an' I wouldn't."

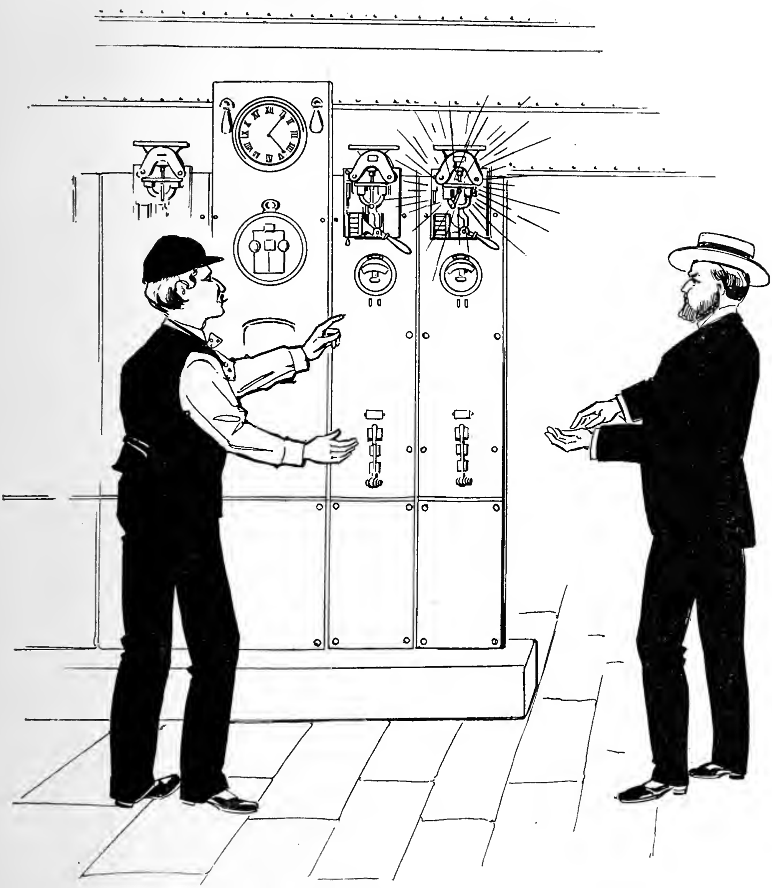
"Mr. Harvey, do you use fuses on your cars?" asked the engineer.

"Why, of course, and——"

"Do you make 'em useless by putting in iron or copper wire instead of fuse-wire?"

"Cert'nly not; what do you think——"

"Then why do you expect me to 'tie-in' a circuit-breaker?"



"They'll hafter wriggle along as best they kin." Bang!

"Why, the d—d thing is going out all the time and stopping my cars, and I can't afford to have 'em stopped every fifty feet."

"Then get rid of the trouble on the cars. I ain't going to tie-in a circuit-breaker any more'n I'd tie down a safety valve on a boiler."

"There ain't any trouble on the cars; it's the crowds we're pulling."

"Well, I'll set the breaker on the fair-ground line a little stiffer; that's the best I can do."

This incident naturally did not promote a David-and-Jonathan friendship between the two chiefs. Nor did it enhance the engineer's peace of mind, for he knew that the heavy travel could not be the sole cause of the frequent "going out" of the circuit-breaker on the fair-ground end. That night he dropped a note to Jones, part of which ran thus:

"The circuit-breaker kept going out every few minutes, but it was not the steady pulling that threw it. The ammeter needle would nearly knock a hole in the side of the case each time the circuit-breaker went out. What made the sudden jerking on the line?"

Jones' answer was characteristic and gave the engineer an opportunity to deliver some sarcastic remarks to Mr. Harvey.

"Your d—d fool motormen were starting their cars on the fourth or fifth controller notches instead of the first or second. Call 'em down hard."

A few weeks later Jones dropped in on the engineer.

"Had any more trouble with circuit-breakers?" he asked.

The engineer grinned. "No," he said, "not since I gave 'em the meat of your letter."

Jones chuckled. "Harvey's all right enough," he said, "but he's new—dreadfully new. When he's seasoned he'll be a good man. Everything else all right?"

"Yes, except we've been troubled a little in balancing the generators when both are in."

"What do they do?"

"They get out of balance as the load increases, and sometimes it's so bad the boy has to stand by the rheostat until the heavy load hour is over."

"Funny," said Jones. "I s'pose you've looked 'em over."

"Best I knew how," said the engineer.

"Feel of the field coils while they were running?"

"Yes, and tested 'em out when we shut down."

"Haven't changed any field connections?"

"Not a bolt."

"H'm," grunted Jones reflectively. "Funny. Let's take a look again."

They examined the generators from top to bottom, but Jones found nothing wrong.

"If it ain't in a generator it's bound to be in the equalizer," he said after a few moments.

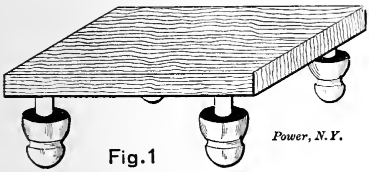


Fig.1

So they inspected the equalizer leads from the generators to the switchboard. Arriving at the back of the board Jones fingered the connections gingerly, standing on an insulated stool (Fig. 1). In a few moments he emitted another grunt, this time of satisfaction.

"See here," he called out to the engineer, who left his inspection of the neighboring generator panel and "saw here."

"Equalizer might almost as well have been in Africa."

"What's wrong?"

"Nuts jarred loose so that the end of the equalizer lead was barely touching the nut next to it."

Sure enough, the connection was so loose that the wire terminal had pulled away from the stud shoulder and was resting lightly against the nut, as shown by Fig. 2. After Jones had set up the nut and jam nut with a wrench, the two men looked at each other, Jones with his usual grin and the engineer with a crestfallen air.

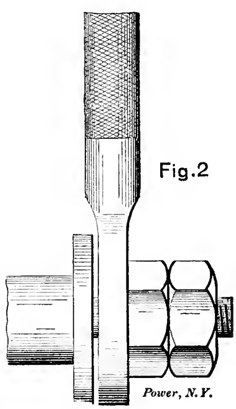


Fig.2

"Simple, wasn't it?" stepping out from behind the board.

"Yes;" said the engineer, following him, "and if I hadn't so busy crowing over Harvey I'd have found it, I s'pose."

"Might not," said Jones. "Simple troubles like that are harder to locate than big ones. You see, I knew it *had* to be the equalizer circuit somewhere because if the field coils were all right the only thing that could keep 'em from balancing would be resistance in the equalizing circuit."

"But the connection wasn't broken; I should think it would balance the generators even if it was a poor contact."

Jones resorted to his favorite pastime and drew Fig. 3.

"It did balance for a light load, but when the current went up to a hundred ampères or so the 'drop' in the equalizer circuit at *r* was so great that enough current wasn't forced across from *a* to *b* or from *b* to *a* to balance the machines."

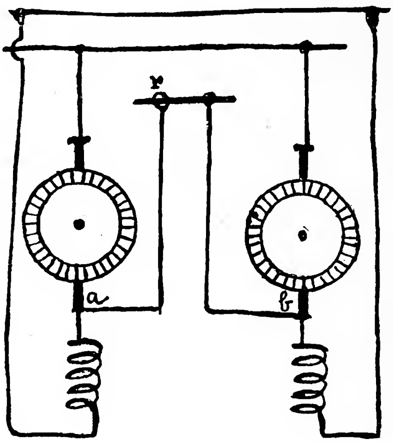


FIG. 3.

"But *some* current must have gone over from one machine to the other?"

"Yes," with a chuckle; "if it hadn't you'd have been sitting up with the corpse of an armature—and maybe an engine."

A SPARKING MOTOR — MOTOR WIRING.

Jones appeared one day in the doorway of a little den which the engineer had partitioned off for a "testing room," and found the engineer with knitted brows and a generally puzzled demeanor, regarding a little motor which was buzzing away at full speed.

"What are you playing?" he asked; "special kind of solitaire?"

The engineer switched off the motor. "Yes," he said, with a semi-smile, "I'm trying to find the key to the pure cussedness of that motor."

"What does it do?"

"Runs like an angel down here and sparks like h—l up at the coffee store. Commutator's been turned off twice in three months."

"Thought angels always flew," commented Jones. "Pictures of 'em indicate that style of motion. What is there up at the store to cause any difference in the motor?"

"Nothin'."

"Oh, yes; there is."

The engineer gazed at Jones' smiling visage in astonishment.

"How do you know?"

"If the motor works differently up there, the local conditions must be different. Simply changing its location can't affect it."

"No, of course not. But there ain't a thing in sight to affect it."

"Take a portable voltmeter and let's go up when the motor goes."

Arriving at the coffee store, the motor was set up in its accustomed place and when put to work it sparked viciously at the brushes.

Jones looked on in silence for a few moments and then began to chuckle.

"I don't see anything to laugh at," complained the engineer.

"I'm not laughing. I'm only wondering how you expect that motor to run smooth when you've got the field magnet almost short-circuited."

"Where's any short-circuit?" demanded the engineer.

Jones pointed in silence to a big I-beam immediately over the motor, which was set on a little platform hung from the I-beam.

"That doesn't touch the motor."

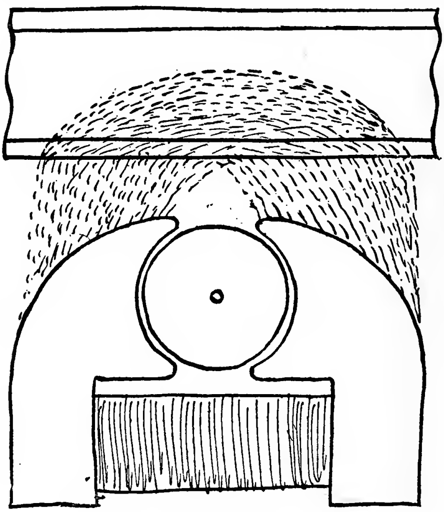


FIG. 1.

"It doesn't need to," said Jones. Don't you know you can't insulate magnetism?"

"I don't know just what you are driving at," said the engineer.

Jones cut off the motor. "No use to let it chew up that fresh commutator surface," he said. "Now see here," and he drew Fig. 1.

"Those dotted lines represent magnetism leaking across from your field magnet to the I-beam. The result is that your field is weakened.

"So that the armature reaction causes sparking?"

"Exactly."

"It will run above speed until the load becomes too great for it to pull at the higher speed. Try it."

The motor was turned on. With no load it ran at a high rate of speed. With two coffee grinders connected up it slacked down considerably and sparked fiercely at the brushes.

"Turn it around so the pulley will be in the same place, but the motor will be out from under that I-beam," suggested Jones.

"Why doesn't it run faster then?"

"I don't see anything to laugh at."

When this was done the motor ran smoothly and without a spark, but the speed slacked greatly when the load was increased.

"Connect up the voltmeter and read it at no load and full load."

The engineer did so.

"No load 229 volts; full load 213," he reported. "Wires too small?"

Jones nodded.

"Better get a good wiring table or set of 'em," he said. "You'll need all kinds and conditions of wiring before long."

"What size should these leads be?" asked the engineer.

"What size are they now?"

"No. 10," after inspection.

"Then they should be either No. 7, or Nos. 6 and 8."

"What do you mean by Nos. 6 and 8?"

"One leg No. 6; the other No. 8. Here, take my motor wiring table and use it until you get a wiring book," and he took from his note-book a sheet containing the table here reproduced.

MOTOR WIRING TABLE.

110 Volts. — Figures at top of columns are Wire Numbers, B & S. gauge. Figures in body of table are distances in feet from main line to motor; *i. e*, the actual length of one wire. The Table is computed for a drop of $3\frac{6}{10}$ to $3\frac{65}{100}\%$. — 220 Volts.

Horse Power	Actual Amperes.	2	2 & 3	3	3 & 4	4	4 & 5	5	5 & 6	6	6 & 8	8	8 & 10	10	10 & 12	12	12 & 14	14	Actual Amperes.	Horse Power.
¼	2½	....	....	....	....	....	....	....	....	....	....	....	....	784	638	490	400	290	5	
	¾	....	....	....	....	....	....	....	....	....	....	....	922	712	580	448	364	280	5½	1
	3	....	....	....	....	....	....	....	....	....	....	....	845	652	530	410	334	258	6	
½	4½	....	....	....	....	....	....	....	....	....	896	692	563	434	354	274	223	172	9	
	6	....	....	....	....	....	....	....	....	990	807	623	508	392	319	245	200	145	10	2
	5½	....	....	....	....	....	....	....	....	900	733	566	460	356	290	224	182	140	11	
	6	....	....	....	....	....	....	....	933	825	672	519	422	326	265	205	167	129	12	
¾	6½	....	....	....	....	....	....	960	860	762	620	479	390	300	245	190	154	119	13	
	7	....	....	....	....	....	....	892	799	707	576	445	362	279	227	176	143	110	14	3
	7½	....	....	....	....	....	940	832	746	660	536	414	338	260	212	164	132	102	15	
1	8	....	....	....	....	984	882	780	699	619	503	389	316	244	199	154	125	96	16	
	9	...	....	....	988	875	784	694	622	550	448	346	280	217	177	137	110	86	18	4
	10		....	993	890	787	705	624	559	495	403	312	254	196	159	123	100	77	20	
	11	....	....	903	809	716	640	567	508	450	366	283	230	178	145	112	90	70	22	5
	12	....	935	827	740	656	588	520	466	412	336	259	210	163	132	102	83	64	24	
1½	14½	863	774	685	614	543	487	430	385	340	277	214	174	135	109	85	69	53	29	
	15	834	748	662	593	525	470	416	373	330	268	207	169	130	106	82	66	50	30	
	16	782	700	620	556	492	440	390	349	309	250	194	158	122	99	77	62	48	32	7½
2	17	736	660	584	524	463	415	367	329	290	237	183	149	115	93	72	58	45	34	
	18	695	623	550	494	437	392	347	310	275	224	173	140	108	88	68	55	43	36	
	19	659	690	622	468	414	370	328	294	260	212	164	133	103	84	65	52	40	38	
	20	626	660	496	445	393	352	312	279	247	200	156	127	98	79	60	50	38	40	
	21	596	528	472	423	375	335	297	265	235	190	148	120	93	75	58	...	..	42	10
		569	510	452	404	358	320	283	254	225	183	142	115	89	72	56	....	....	44	
3	26	480	432	382	342	303	270	240	215	190	155	120	98	75	60	48	....	....		
	27	463	415	368	330	292	260	230	209	187	150	115	93	72	59	46	....	....		
	28	447	400	354	318	282	252	223	199	177	144	110	90	70	57	44	....	....	56	
	29	432	387	342	307	272	243	215	192	170	138	107	87	67	54	42	....	....	58	15
	30	417	374	330	296	262	235	208	186	165	134	103	84	65	....	....	....	....	60	
5	38	329	295	260	234	207	185	164	147	130	106	82	66	51	....	....	....	....	76	
	40	313	280	248	222	196	176	156	139	123	100	78	63	49	....	....	....	....	80	20
	42	92	264	236	210	187	167	148	132	117	95	74	....	....	....	....	....	....	84	
	44	284	255	226	202	179	160	140	127	112	91	71	..	....	....	....	....	....		
	46	272	243	215	193	170	153	135	120	107	87	67	....	....	....	....	....	....		
7½	56	223	200	177	159	140	126	110	99	88	72	65	....	....	....	....	....	....		
	58	216	193	170	153	136	120	107	96	85	....	....	....	....	....	....	....	....		
	60	208	187	165	148	130	117	104	93	82	....	....	....	....	....	....	....	....		
	62	202	180	160	143	127	113	100	90	80	....	....	....	....	....	....	....	....		
	64	195	175	155	139	123	110	98	87	77	...	....	....	....	....	....	....	....		
10	72	174	156	138	123	109	98	87	77	68	....	....	....	....	....	..	....	....		
	74	169	151	134	120	106	95	84	....	....	....	....	....	....	....	....	....	....		
	76	164	147	130	117	103	92	82	....	....	....	....	....	....	....	....	....	....		
	80	156	140	124	111	98	88	78	....		....	....	....	....	....	....	....	....		
Wire Nos.		2	2 & 3	3	3 & 4	4	4 & 5	5	5 & 6	6	6 & 8	8	8 & 10	10	10 & 12	12	2 & 14	14		
Safe Current		130	1 0	110	92	92	77	77	65	65	46	46	32	32	23	23	16	16		

The engineer thanked him, and they started back to the station.

"Why did you say awhile ago that I'd need all sorts of wiring soon?" asked the engineer.

"Because you will. The town has about decided to put in an alternator and to lease the old water-power and mill site up the river so's to furnish light and power to the shops and factories out at the west end, and you're going to do a lot of wiring calculations."

"But I don't know how exactly."

"You can learn."

Reaching the station the engineer took out Jones' wiring table and spread it on the desk.

"Why are there several numbers of ampères for each size of motor?" he asked.

"Because different motors show different efficiencies, and therefore require different amounts of current."

"That's so. According to the table this motor will need Nos. 6 and 8 wire, just as you guessed."

"I didn't guess; I knew."

"How could you know?"

"With No. 10 wire your drop is 16 volts, isn't it?"

"Yes."

"Well, seven or eight volts is as much as you ought to have on a 220 or 230 volt circuit. And in order to cut your drop down from sixteen volts to about eight, your wire must be about twice the size it is."

"Yes, but——"

"Wait. No. 7 wire is roughly twice the size of No. 10, but No. 7 wire is not generally kept in stock. As No. 7 is about half way between No. 6 and No. 8, making half of your circuit of No. 6 and the other half of No. 8 will give practically the same result."

"I don't exactly see that."

"No. 6 wire has an area of 26,250 circular mils," referring to his notebook, "and No. 8 has 16,510 circular mils. Now if half of the circuit is of one size and half of the other size, the average area throughout the circuit will be the plain average of these two areas. What is the average or mean of 26,250 and 16,510?"

The engineer wrote:

$$\begin{array}{r} 26{,}250 \\ 16{,}510 \\ \hline 2)42{,}760 \\ \hline 21{,}380 \end{array}$$

"Twenty-one thousand, three hundred and eighty circular mils," he said.

"All right. Now No. 7 wire has an area of 20,817 circular mils, so that Nos. 6 and 8 used together give slightly less drop than No. 7 would."

"I see. And Nos. 10 and 12 can be used instead of No. 11; Nos. 8 and 10 instead of No. 9, and so on?"

"Exactly. Thus you get a greater number of available wire areas or resistances without carrying any more sizes in stock."

The engineer pored over the wiring table for several minutes.

"Suppose I wanted to wire a 5-horse motor and didn't know how many ampéres it would take?" he suggested.

"Assume the middle figure, in such a case. The wiring will be near enough for all practical purposes."

"Forty-two ampères for a 110-volt five-horse, and twenty-two ampéres for a 220-volt five-horse?" he asked.

"Yes."

"How can you use the table for some other percentage of drop?"

"Multiply the actual ampères by the drop you want, divide by 3.6, and use the result as if it were the ampères your motor demanded. But I wouldn't bother with any other drop. Three and six-tenths per cent is a good all round drop and will fit any case within reason. Get your wiring book—but get a good one that contains something more than kid lessons on Ohm's law—and you will have tables for all practical drops. Be sure it includes alternating-current wiring."

"Is that any different?"

"Considerably. Direct current wiring tables are no earthly good for alternating-current circuits."

SOME RAILWAY KINKS.

Since the circuit-breaker episode Mr. Harvey and the engineer had become better acquainted, and each had discovered, as usually befalls, that the other had "lots more sense" than he had supposed. Moreover, Harvey's "newness" had worn off greatly, and he had come down to an appreciation of his own limitations. If

"The old man'd raise cain."

I may be permitted to digress a little from the historical to an advisory line, I would like to urge upon young engineers the fact that an accurate weighing of one's own ability, coupled with confidence and a determination to improve, results in success ninety-nine times in a hundred.

Harvey was rapidly attaining this frame of mind; hence he and the engineer found mutual benefit in frequent consultations, and appeals to Jones' superior experience were not so often necessitated as they had been previously. Thus it happened that Harvey called on the engineer one day nearly a year after the circuit-breaker occasion, for "consultation."

"It's mighty nigh time for that old fair ag'in," he said, "and we'll have to do something to provide for the crowds."

"Got no extra cars?" queried the engineer.

"Oh, yes; plenty o' cars. But the feeders out there ain't calc'lated to keep up the pressure with such heavy loads."

"We might run some temporary feeders—hang 'em up from the cross-arms by loops from porcelain knobs," suggested the engineer.

"Lot o' work, and the wire's bound to be more or less damaged."

"Yes. Really, the feeders ought to be reinforced permanently so's we could carry extra loads."

"The old man 'd raise Cain if I asked him to put in that much extra wire just for the fall fair."

"Figured out what 'twould take?"

"Roughly. We've got three feeders out there now; a mile o' No. 2, two miles o' No. 00 and three miles o' No. 0000 wire. The drop with two cars, one going out and one coming in, is about 60 volts, so we'd need to put in two more sets o' feeders to handle six cars at the same drop."

"That's so, or nearly so. You'd need two more No. 0000 feeders out to the far end; a No. 0000 near the middle and a No. 00 out to the near end of the branch line. Eight miles of No. 0000 and a mile of No. 00. Whew!"

Harvey nodded gloomily.

"That's what I figured out, and I might's well ask the old man for a pair o' gold wings as all that wire."

Suddenly the engineer jumped up and said emphatically:

"Well I'll be d——d."

"That won't help the cars any," said Harvey, but he brightened up under the influence of the engineer's jubilant countenance.

"What's struck you?"

"Booster," sententiously.

"You did seem to get a pretty good lift out o' that chair. Where's any booster?"

The engineer took Harvey by the coat lapel, and leading him out into the dynamo room, pointed dramatically towards the dynamos and said: "There!"

"Is it wheels you've got, or snakes?"

The engineer laughed and went back in his den.

"See here," he said, drawing a diagram like Fig. 1 and remarking, "I'm getting into Jones' habits."

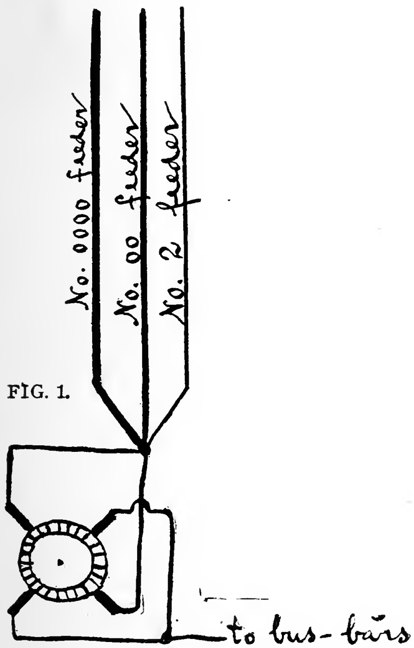


FIG. 1.

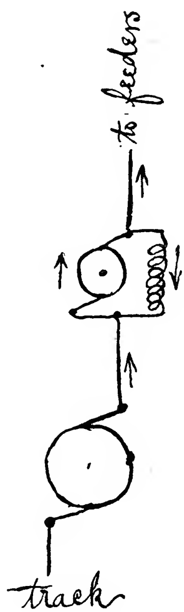


FIG. 2.

Harvey looked on in silence.

"All we need to do is to disconnect your three fair-ground feeders from the bus-bars and put one of my 500-light dynamos in series with all three of them, like that."

"Goin' to leave her self-exciting?"

"Yes; why not?"

"Lemme draw a little," said Harvey, with a smile. And he drew Fig. 2.

"I was just wondering about the current in that field circuit,"

he said. "The current must go like the arrows for the dynamo to work; now won't the generators force current backward through the booster dynamo's field?"

The engineer hesitated.

"I don't think so," he said. "You see, the E.M.F. that forces current through the dynamo field is furnished by its own armature."

"Yes; but the railroad generator is furnishing the most of the E.M.F., and the current going out on the line must divide when it comes to the dynamo, part'll go through the armature and be boosted, and a little will go through the field——"

"And be kicked back. No; I don't believe any of the feeder current will get through the field circuit of the boosting dynamo."

"Well, well, well; what's the game?" broke in a familiar voice, and Jones' chubby visage seemed to fill up the entire doorway.

"You always turn up at the right minute," said the engineer——

"Born that way," broke in Jones. "What's up?"

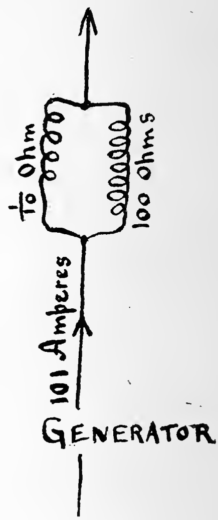


FIG. 3.

The case was soon laid before him, and his usually sunny countenance clouded slightly.

"I'll be ashamed of you fellows if you don't use your brains more. Why should you be in doubt about it?"

"Well, we—that is—of course—" stuttered Harvey.

"Suppose," said Jones, drawing Fig. 3, "you had this condition. What would be the joint resistance of the two coils in parallel?"

The engineer scribbled hurriedly, with the result below:

$$\text{Resistance } \tfrac{1}{10} = \text{Conductance } 10$$
$$\text{"} \quad 100 = \text{"} \quad \tfrac{1}{100}$$
$$\text{Total conductance} = 10 + \tfrac{1}{100} = 10.1$$
$$\text{" resistance} = \tfrac{1}{10.1} \text{ or } \tfrac{10}{101}.$$
$$\begin{array}{l} 101)\,10.000\,(.099 \\ \quad\ \ \underline{909} \\ \quad\ \ \ 910 \\ \quad\ \ \ \underline{909} \end{array}$$

"Ninety-nine thousandths of an ohm," he announced.

"Then what's the drop if the current is a hundred and one ampères?"

"Ten volts," after scratching for a few seconds.

"Then if the left-hand coil became an armature giving one hundred to one hundred and ten volts, do you think the ten volts originally at the terminals of the field coils could overcome it and force current through backwards?"

"I never said it would," asserted the engineer; "but I wasn't absolutely sure about it," he confessed.

"You will have to be careful, though," said Jones, "in using that arrangement. The feeders must be disconnected until the dynamo has picked up and reached its full field strength."

"What difference would it make?"

"Reason it out and see."

The engineer and Harvey studied Fig. 2 a few moments.

"If it was put in circuit not running," said Harvey, "the field would be excited backwards and when the dynamo started it would oppose the feeder current instead of helping it."

"Exactly. That is one reason why a series-wound booster is preferable. The principal reason, however, is that the more current there is the more voltage the booster adds, so that the E.M.F. at the far end may be kept absolutely constant no matter what the load is."

"There's something else I'd like to ask you," said Harvey. "I've got a car that runs at the same speed on the last controller notch that it does on the one next to it. Why is that?"

"What kind of a controller?"

"K2."

"Nothing seems wrong anywhere else?"

"No. The controller contacts are all right, and there ain't a sign o' trouble anywhere."

"H'm. Which controller notch is the speed correct for?"

"Dunno."

"Then you might profitably spend a while finding out. If the car runs at full speed on the eighth notch that notch has become the same as the ninth, by some accidental contact. If the car never gets beyond the eighth notch speed, then the ninth notch is 'killed' by something wrong."

"What could be the trouble in each case?"

"If your car runs slow on the ninth notch, the shunt resistances are not connected. If it runs at full speed on the eighth notch, then the shunt resistances are thrown in at that notch instead of the ninth. The trouble is almost certainly in the shunt resistance circuit, no matter whether the result is eighth-notch speed at both notches, or ninth-notch speed at both. It's more likely to be disconnected shunt resistances than accidental contact between controller fingers. Test out your shunt resistance circuits and you'll find it."

READING A RECORDING WATTMETER.

"Harvey, do you know anything about meters?" asked the engineer, plaintively, as he watched the dignified rotation of a Thomson recording watt-hour meter.

"Divil a bit," replied Harvey, who boasted a Celtic ancestor and occasionally took this method of manifesting his pride therein. "What's the trouble?"

The engineer rubbed his chin abstractedly and gazed at the meter again.

"It seems to run all right up here," he explained, "but it don't register anywhere near right at Briggs' store."

"How d' you know 'tain't right?"

"Well, Briggs' bill was so derned triflin' last month and the month before, I knew the' must be a screw loose somewhere. So I had Jimmie take ammeter readin's for an hour yesterday, 'n' the meter registered short."

"What kind o' load has Briggs got?"

"What's that got to do with it?"

"I dunno," responded Harvey, frankly. "Over to Durham, where I was before I come here, they had a lot o' these on, an' I remember Perkins told the meter man there 't the' wa'n't no use 'xpectin' a meter to *talk;* 't 'twa'nt intended for that kind o' load."

"What kind of a load did he mean?" asked the engineer, anxiously.

"Dunno that," again acknowledged Harvey, "but it's evident that the's *some* kind of a load the fool things ain't good for."

"It seemed to run all right before we put in that other motor," said the engineer.

"What other motor?"

"The little freight elevator motor."

Harvey's face lightened.

"Then that must be the kind o' load Perkins meant," he exclaimed.

The engineer shook his head dubiously and turned off the current from the meter under discussion.

"Jones didn't say anything about it when he brought the first meters here," he said.

"Probably didn't think of it. You didn't have any elevator motors running then, did you?"

"N—no."

" 'Spose we try the meter on the main load, with the elevator motor tapped in between the entrance and the meter," suggested Harvey.

"That's good," agreed the engineer, and the test was made, Jimmie, the general utility boy, being delegated to take ampère readings every five minutes for an hour. The results checked nearly enough to show that, allowing for the possible division of Jimmie's attention between the ammeter and a blood-and-thunder novel, the recording meter was accurate.

The engineer looked at Harvey and Harvey grinned triumphantly.

"That's it," he said.

"Evidently; but what'll I do about the elevator motor?"

"Got a recording ammeter?"

"Yes; there's three on the station switchboard."

"Borrow one of 'em and put it in the elevator motor circuit for a week and make 'em a flat rate based on what the ammeter charts show. Put another wattmeter in and keep this one just as it is to show Jones."

This course was pursued, after a lively interview with Briggs, who was crusty and difficult to convince.

Shortly thereafter the engineer related the experience to Jones.

"Now, why won't the recording meter register elevator motor current as well as any other kind?" he asked.

"Do you know what inertia is?" was Jones' counter-question.

"Of course."

"Well, then you know that the armature of that meter possesses the quality called inertia, which tends to prevent any change in speed."

"Yes, but——"

"Hold on. You also know that the speed of the armature is almost precisely proportionate to the power of the circuit?"

"Yes; that's why——"

"Don't get excited. Now, suppose your circuit has, say, 2 horse power passing, and the motor makes, say, 10 revolutions a minute. Then imagine that your elevator motor is thrown on and the power changes instantaneously to 10 horse power; do you suppose the meter armature can change its rate from 10 to 50 revolutions a minute *instantaneously?*"

"N—no, of course not, but——"

"All right. Now imagine that the power drops immediately to 4 horse power, after that spurt up to 10. Don't you see that the meter can't possibly shift its rate of speed rapidly enough to register all the changes accurately?"

"Yes, that's clear enough, but the spurts don't last long enough to make any great difference."

"Not a tremendous difference, perhaps, but with a motor constantly starting and stopping, the difference will be fairly big. How much discrepancy did there seem to be?"

"Not very much the first month, but simply out o' sight the second month."

"Then your boy read the meter wrong. Let's see the record book."

The book was found to contain the following entries:—

Name	October		November		December	
Briggs, D. 2	10	6,228,800	10	7,999,400	12	8,927,500
		4,952,600		6,228,800		7,999,400
		1,276,200		1,770,600		928,100

"H'm," grunted Jones. "Where's the boy?"

Jimmie was summoned, and after some delay came running in with a suspicious show of zealous haste.

"Jimmie," said Jones, in his most confidential, persuasive tone; "Jimmie, how did you get at the reading of Briggs' meter this month?"

Jimmie turned as many colors as the possibilities of nature

allow; stood on one foot, then on the other; looked over Jones' head, then at the hat he was nervously twisting between his hands, but was apparently dumb.

"Guessed at it, didn't you, Jimmie?" asked Jones in such an unmistakably friendly tone that Jimmie thawed and broke down.

"Y—y—yas, sir," he stammered, digging his grimy knuckles into his eyes to keep back the tears.

"Now, don't cry, Jimmie," said Jones. "I was a kid once and learned the same sort of lesson you're learning now. Hereafter, though, when you're not sure of a thing don't be afraid to say so, or else find out what's correct before you report on it."

"I did—didn't g—guess at o——o only one figger," sobbed Jimmie in an effort at partial justification.

"Which one?"

"The f—fust one. 'Tothers is r—right."

"All right. Now skip, and stop crying," which Jimmie did with alacrity.

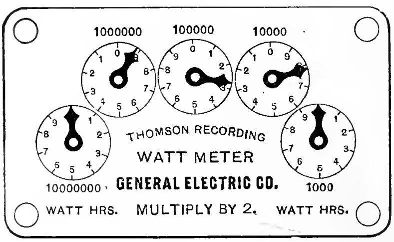


FIG. 1.

"Makes me chicken-hearted to see a kid cry," said Jones, sheepishly. "Got the Briggs meter out of service?" he asked.

The engineer brought it.

"Don't blame Jimmie very much for guessing," said Jones, pointing to the dials, which stood as shown by Fig. 1. "Can you read 'em?"

Harvey and the engineer looked at the dials and said in one voice:

"Nine, two, eight, zero."

"Precisely *not*," said Jones with a grin.

Harvey and the engineer stared at him and then at the dials.

"What *does* it register?" asked the engineer.

"Nine, nine, two, eight, zero."

"Where's the first nine?"

"Begin at the right-hand dial and you'll see. That's zero; next one's not quite eight, but it must be eight because the first one is at zero. Next one's not quite three, so two is right. Next one is at nine, and the last one seems to be at zero, but it can't reach zero accurately until the one on its right does. Therefore it must be considered *not quite* up to zero, making the reading 9,928,000. When it does reach zero, the last dial can be read 10, the one being prefixed because the hand will have made one revolution."

"Oh! But where did Jimmie get the first 8?"

Jimmie stood on one foot, then on the other.

"He read the meter 927,500, and knew that must be wrong, so he prefixed a figure one unit larger than last month's register. Quite a natural error."

"That's so," assented the engineer. "But even the corrected reading is smaller than the average rate shown by the recording ammeter."

"Yes, because that is more sensitive, naturally enough."

"Well, is there no way to make these meters record the sudden changes in the elevator motor load?"

"Not accurately. It will be sufficient to allow two per cent extra for them, though. The meter will average up to within that."

Jones rose to go.

"Hold on a minute; there are some other things," cried the engineer. "Why didn't they make these meters to read direct instead of multiplying the reading by 2?"

"Because the speed would be twice as high, and the inertia of the armature would interfere with the accuracy four times as much as it does now."

"Oh. Well, why do some of the motors creep when there's no load on?"

"Because they are too perfect," said Jones, laughing. "In other words, they move too easily."

"But what is there to make 'em move?"

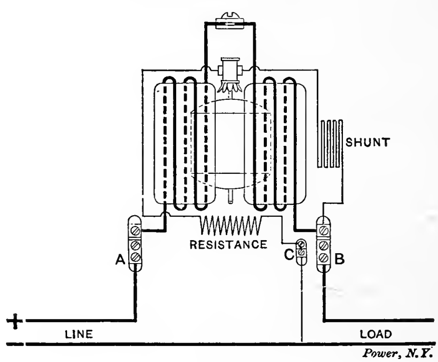


FIG. 2.

Jones took out his note-book and turned to a diagram like Fig. 2.

"If you trace these connections," he said, "you will find that with no lamps on, current will flow from the + line wire through the series field coils between *A* and *B*, then through the shunt coil and armature to *C*, and out to the negative line wire. Although it is almost infinitesimal, this current may cause a meter to creep if it is unusually free running."

"Can't it be remedied?"

"Yes; easily. Transfer the shunt field connection from *B* to *A*, and the meter probably won't creep."

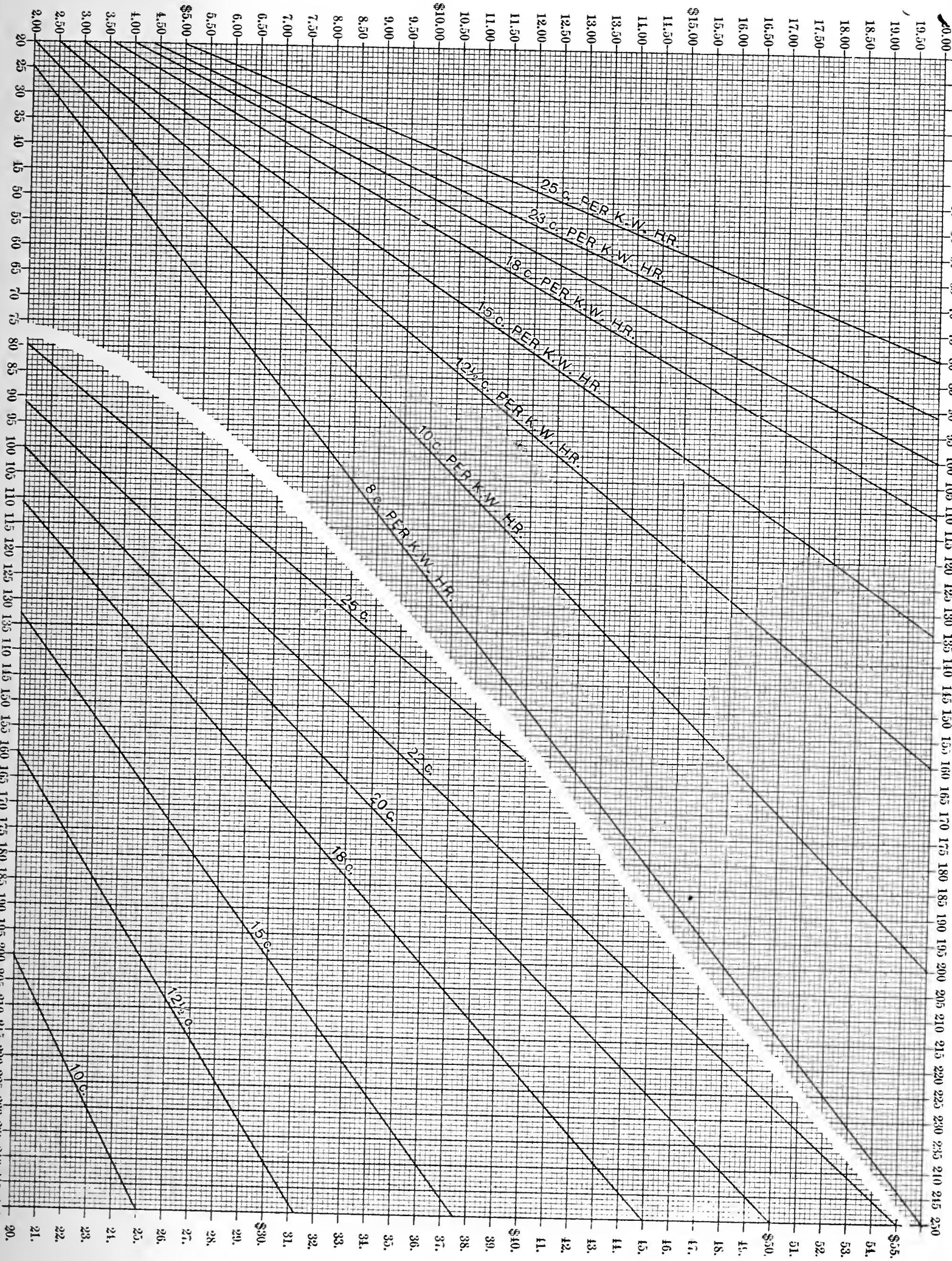


FIG. 3.—ELECTRIC POWER PRICE CHART.

"Why wasn't it fixed that way?"

"Because it is intended to measure only the work done *beyond* it. As it stands it does this. If you change the shunt field connection over to *A*, the meter will register the work done in its own series coils in addition to the customer's load. But the increase is unimportant."

As Jones closed his note-book a sheet of paper fluttered to the floor.

"Hello," he said, as he picked it up and opened it. "I brought that for you and forgot to give it to you."

It was the price-chart shown by Fig. 3. This chart is divided into two parts by the white space cutting diagonally across it. Above this dividing line the figures up the left-hand margin must be used; below it, the figures along the right-hand margin. To use the chart, find the number of kilowatt-hours on the top or bottom line of the diagram; follow vertically along that line until the diagonal line representing the price per kilowatt-hour is reached; then follow the horizontal line there found over to the margin. At the end of it will be found the amount of the bill.

BRAKING A CAR WITH ITS MOTORS.

"Say, I've got an idea," exclaimed Harvey one afternoon, as he and the engineer sat basking in the sunshine of a prematurely springlike day.

"You're in dead luck," observed the engineer. "It don't hurt you, does it?"

"No," replied Harvey, good-humoredly; "it's this way. See that car comin' down the West End hill?"

The engineer looked down the river and over toward a hill-side around which a trolley car was slowly creeping, and nodded.

"That infernal hill is more worry 'n all the rest o' the blamed road put together, and I'm goin' to——"

"Have it leveled?" suggested the engineer, chaffingly.

"Not quite; but I'm goin' to fix the cars so's they'll come down there without workin' the men to death and keepin' 'em uneasy all the way down. I'll fix 'em so they can't get beyond a safe speed, even with the brakes entirely off," announced Harvey triumphantly. "What d'you think o' that for a scheme?"

The engineer straightened up and regarded the speaker with renewed interest, and an interrogatory expression of countenance.

"It's bang up if you do it," he replied, "but it ain't done yet."

"No, but it's a cinch, though," asserted Harvey confidently.

"Trailin' anchor?" suggested the engineer.

"Nope. Perfectly automatic brakin' scheme."

"Fiddle," said the engineer, contemptuously. "Automatics ain't any good for street car work. You have to have a whole machine shop aboard and keep two extra men on a car to keep the stuff a-goin'."

"Just you hold on——"

"More'n your blessed brake'll do!"

"See here a minute," argued Harvey; "if I short-circuit the car

motors through a low resistance, like this," drawing Fig. 1, "why won't they generate current and hold the car back?"

The engineer looked at the diagram thoughtfully.

"That's been tried, I think," he said, " and it wasn't a success."

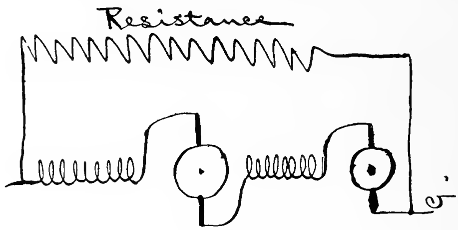


FIG. 1.

Harvey scratched his head and looked skeptical.

"I don't see any reason why it shouldn't work," he said. "It's only a question of gettin' the resistance right so's not to brake the car too heavy or run any risk o' burnin' out the motors."

"Looks that way," admitted the engineer, "but I'm sure it's been tried 'n' failed."

"Well, I'm goin' to give it another chance to fail," asserted Harvey with a grin. "It won't cost much to rig a switch on the dash to make the connection across from outside to outside o' the motors through a resistance."

The engineer studied Harvey's rough sketch for several minutes in silence. At length he asked:

"How about the connections between the motors?"

"Why, the controller makes them."

"Not when it's in the 'off' position."

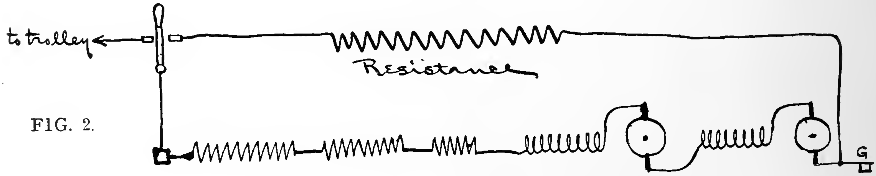


FIG. 2.

Harvey looked puzzled for a moment. Then his face lighted up and he let the front legs of his chair down with a bang and abandoned its comfort to pace up and down excitedly.

"Gee whillikens!" he exclaimed. "That's a dandy scheme!"

"What is?"

"This," and he hastily scrawled the diagram shown by Fig. 2. "If I put in a double-throw switch this way to cut the controller loose from the trolley 'n' connect it to the end of a resistance coil then the brakin' effect o' the motors can be regulated with the controller itself. Ain't that great?"

"It looks all right," agreed the engineer after looking over the diagram carefully, "but I wouldn't trust it 'til I'd tried it and made sure."

"Course not," said Harvey. "How much resistance d'you think it'll take in series with the motors?"

"I don't believe you'll need any extra resistance besides the coils already on the car," said the engineer. "I guess we can get a rough idea of it with a little figurin'. About how much does a car weigh?"

"Close to five thousand pounds."

"And with fifteen passengers and the two men the whole thing'll foot up about eight thousand pounds, won't it?"

Harvey nodded assent.

"What's that grade over there; 'bout ten per cent?"

"Nine, most of the way; the balance of it's less."

"Then if the car comes down at four miles an hour, how many feet a minute is that?"

Harvey multiplied 5,280 by 4 and divided the product by 60. "Three hundred 'n' forty-two," he said.

"Then, if we take the grade at nine per cent the car'll come downward nine-hundredths of three hundred 'n' forty-two feet in a minute; figure that."

"Thirty feet 'n' seventy-eight-hundredths; practically thirty-one feet," said Harvey.

"Now, eight thousand pounds dropping at the rate of thirty-one feet a minute is two hundred and forty-eight thousand foot-pounds a minute, ain't it?"

"Dead sure," agreed Harvey. "You've got a head on you, old man," he added admiringly.

" 'Tain't me," said the engineer modestly; "it's Jones' trainin'. Now let's see how it comes out," he resumed. "We've got two hundred 'n' forty-eight thousand foot-pounds a minute to drive the motors as dynamos 'n' overcome the friction o' the car axles

Let's get that into watts 'n' then we c'n apply it to the motors better. Divide that by thirty-three thousand to get it into horsepower 'n' then multiply it by seven forty-six to get it into watts."

Harvey scribbled for a few moments and then announced:

"Five thousand six hundred 'n' six watts."

"Now, have you got that test sheet that Jones gave you when the road was put in?"

Harvey produced the test sheet from his wallet and silently handed it over to the engineer. The principal data contained by the test sheet are given in the accompanying table.

DATA FROM TEST OF A 30-HORSE POWER RAILWAY MOTOR.

Amperes.	Net Output at 100 Rev. of Axle.		Losses in Watts.	
	B. H. P.	Watts.	Gears and Cores.	Windings.
10	1.65	1,230		179
20	6.28	4,685		785
25	9.47	6,470		1,260
30	11.78	8,788		1,810
40	17.88	13,340	1,500	3,320
50	24.6	18,350	1,550	5,400
60	32.36	24,140	1,760	7,920
70	40	29,840	1,820	11,765
80	48	35,800		16,410

"Your car wheels are 33-inch, ain't they?"

Harvey said they were.

"Then how many revolutions will they have to make if the car runs at three hundred 'n' forty-two feet a minute?"

Harvey consulted a table of circumferences in his note-book, scratched away for a few seconds, and announced:

"Practically forty."

"Then you won't need any extra resistance coils. See here a moment." Harvey stood beside the engineer and looked over the test sheet with him.

"The weight o' the car, fairly loaded, gives us five thousand six hundred 'n' six watts of power, on a nine per cent grade at four miles an hour, don't it?"

Harvey admitted that it did.

"Now, with twenty-five ampères in the motors each one'll develop six thousand four hundred 'n' seventy watts at a hundred revolutions a minute of the axle, or two thousand five hundred

'n' eighty-eight watts at forty revolutions a minute of the axle. That's right, ain't it?"

"Accordin' to that sheet it is."

Harvey stood beside the engineer and looked over the test sheet.

"Then the two motors'll develop about five thousand one hundred 'n' seventy-six watts."

Harvey nodded assent.

"Jones says the iron losses and gear friction don't get much lower than fifteen hundred watts, and the losses in the windings of each motor are twelve hundred 'n' sixty watts, so the total losses in the two motors at twenty-five ampères are about three thousand in the gears and cores and twenty-five hundred in the windings, that's fifty-five hundred watts, or a hundred less'n the weight 'n' speed o' the car give, 'n' a trifle over three hundred watts more'n the motors'll develop at that speed 'n' current. That so?"

"Yes, but if the motors won't develop that much, where's it comin' from?"

"The car'll take the right speed to make the power developed by the motors correspond with the losses in 'em when they're on short-circuit."

"Yes, but what speed'll that be?"

"We can't figure it exactly from this sheet, but it can't be much faster'n four miles because they almost balance at that speed. If she gets a-goin' at too high a rate you can throw your controller 'round to the fourth notch where the resistance is all out."

Harvey went off up to the car barn in a meditative mood and the engineer did not see him for a week or ten days. Then he came down to the power house, the image of woe, and almost ran over Jones, who was just coming out.

Who's dead?" asked Jones, with reference to Harvey's dejected air.

"Hey? What the——. Oh, I didn't recognize you, but I'm awful glad you're here. I'm up a stump."

"Hello, Harvey; how's the brake?" asked the engineer, coming out just at this moment.

Harvey shook his head gloomily and thrust his hands deep in his pockets. "Don't work at all," he said, "and I'll swear it ought to."

Jones looked inquiringly from one to the other. "What have you been up to now?" he asked.

Harvey took out the sketch of the braking connections, handed it to Jones and explained his experiment.

"You say it's no go?"

Harvey nodded and looked hopeful at hearing Jones' doubting inflexion.

"Did you throw your reversing switch before trying to make the motors brake the car?"

"Of course not."

" 'Of course not' " mimicked Jones. "How the devil did you expect the motors to generate any current if you didn't?"

Both Harvey and the engineer stared at Jones in surprise. This was a totally unexpected development.

"See here," said Jones, a little impatiently, drawing Fig. 3.

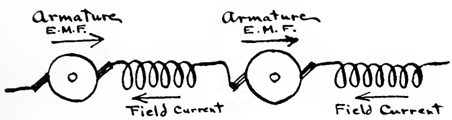


FIG. 3.

"You know perfectly well that when the motors are running as motors the current passes through from the line in opposition to the counter E.M.F. of the armatures, as these arrows show. Consequently, if you want to make them furnish their own exciting current you've got to reverse the connections between the armature and field of each motor—in other words, throw your reversing switch. Then the armature E.M.F. will be in the same direction as that required by the field for its excitation. Do that and your brake'll work like a house a-fire."

"Well, I'll be d—d!" ejaculated Harvey.

"Don't doubt it in the least," assented Jones cheerfully.

ENLARGING A RUNNING STATION—THE MOTOR-BALANCER

"Well, old man," said Jones one day, on the occasion of one of his periodical visitations to the engineer, "I've got a nut for you to crack now," and he chuckled in his usual boyish fashion at the prospect of "stumping" his hearer.

The engineer pondered for a moment before replying.

"It's got something to do with the additions that are going in, I'll bet a cookie," he said.

Jones nodded energetically. "You've struck it, my son," he admitted. "You know that the council has arranged with the Freeport people to furnish lights over there and save 'em the trouble of putting in a plant?"

The engineer said he did.

"You also know that your folks are going to put in two 1,000-light alternators for that purpose and to also take the incandescent load around here?"

The engineer again acknowledged having been informed.

"And that we can get only one more engine and generator in here without extending the engine room; also that while there is ample room for extension to the boiler room, this part of the shanty is hemmed in by other property, so that it would be extremely expensive to get more room?"

"No, I didn't know that."

"Well, it's so, and the puzzle that confronts you now is to provide for continuous service from the existing plant during the installation of two alternators when you have room only for one, and that without interrupting the service from the present plant a single minute." Jones grinned as he sauntered toward the door. "I'll be back to-morrow and see what sort of solution you have to propose."

"Hold on there," called the engineer; "what's going to be done with these machines that are running now?"

Jones turned on his heel. "That's part of your problem," he said, and departed.

The engineer looked at his dynamos, scratched his head, and telephoned to Harvey to come down to the power house. When Harvey arrived he repeated what Jones had said, and looked interrogatively at the superintendent for an expression of opinion. Harvey stood staring at the generating plant and the vacant floor space for a few moments, and then took his way into the engineer's little den, followed by the owner of the den.

"One thing's certain," said Harvey, by way of establishing a premise; "you've got to take out your small 110-volt dynamos and their engine before you can put in the two alternators."

The engineer assented. "But we can put in one alternator and its engine before disturbing anything at all," he said.

"Yes; but that won't take care of the 110-volt motors that are supplied on each side of your neutral wire," said Harvey. "You can't shut them down, although they amount to a very small part of your motor load now."

"That's true," agreed the engineer. "But what's going to happen to them after both the alternators are in? These two small dynamos have got to go out, anyhow; and after they are gone I can't run the 110-volt motors at all."

Harvey scrutinized the ceiling, aimed a vigorous expectoration at the mascot cat purring drowsily on top of the engineer's new felt hat, at imminent risk of ruining the headgear, and finally shrunk up in his chair with his own hat pulled down over his eyes and his hands thrust deep in his pockets. The engineer awaited the evolution of Harvey's ideas, cudgeling his own brain meanwhile for a solution of the problem.

"I can't imagine but two ways out of it," finally announced Harvey.

"Let's have 'em," requested the engineer.

"Either the 110-volt motors 'll have to be replaced by 220-volt ones, or else Jones expects to put in alternating-current motors in their places as soon as the first alternator is in."

The engineer shook his head dubiously.

"I don't believe it's as simple as that," he said, "or Jones

wouldn't have talked about putting in *both* alternators without disturbing the service. That sounded like he expected to put both of 'em in at the same time."

"Might 've been tryin' to catch you," suggested Harvey.

The engineer again signified his lack of assent by a shake of his head.

"I've been wonderin' if it isn't something like this," he said, drawing a rough sketch like Fig. 1.

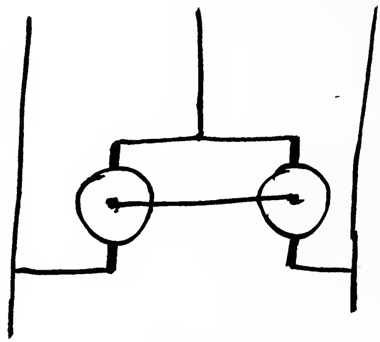


FIG. 1.

"What the dickens is it?" asked Harvey.

"A motor-balancer," said the engineer. "I'm not quite sure about it, but I think they use something like that to balance the two sides of a three-wire system where they have one dynamo connected to the outside wires."

"How does it work?"

The engineer looked puzzled. "I'm darned if I know," he admitted, shamefacedly, "but I'm sure that's the kind of a rig I saw described several months ago for doin' that very thing."

"What is it?" persisted Harvey; "what does it look like life-size?"

"It's two dynamos or motors exactly alike, with their shafts coupled together."

"If they're dynamos they must have something to drive 'em," said Harvey.

"Well, they don't."

"Then what makes 'em run?"

"Confound it, I don't know, I told you. If they're motors, I s'pose the line current makes 'em run."

"What good'll it do to put 'em in, anyway?"

"Why, they don't take up much room, and I can put 'em any place around the plant without usin' the floor space that the alternators are goin' to take."

On the following morning there was a solemn conclave in the engineer's den, Jones, Harvey and the engineer constituting the debating body.

"Well," began Jones, "have you solved the problem?"

The engineer hesitatingly produced his sketch and submitted it without a word. Jones glanced at it and beamed.

"You've hit it first pop," he said; "I'm proud of you. Now let's hear how you propose to go about making the change. I'll tell you this much: the little dynamos are going out for good, both of 'em."

"I supposed so."

"Why?"

"Because there won't be room for both of 'em, and one wouldn't be much good alone."

Jones patted the engineer approvingly on the shoulder.

"You won't need me much longer," he said. "Now for the change."

"Well, I'd put in the motor-balancer first," ventured the engineer.

"Well, what next?"

"Take out the two small dynamos."

"Not so fast. Your two small dynamos carry a good-sized part of the load at night, between 5 and 9 o'clock, and a motor-balancer doesn't carry anything; it simply balances out the difference between the two sides."

The engineer's face fell.

"Don't give up so easy. Try again."

"What's the matter with putting in a bigger 250-volt dynamo in place of the one in now?" suggested Harvey.

"That'll come later on," said Jones, "but it isn't part of the present plan."

"What size will the alternators be?" suddenly asked the engineer.

"Fifty kilowatts each," replied Jones.

The engineer brightened up again.

"What a derned fool I am," he said, disgustedly. "The two little machines are 500 lighters, and their engine is a hundred horse-power, indicated. That engine 'll run one of the alternators."

"Most assuredly," said Jones, encouragingly. "Go on."

"We'll have to run the alternating-current primary wiring and put up enough transformers to carry the capacity of one alternator; then put in an alternator in place o' the two little dynamos in the motor-balancer on the 230-volt circuit."

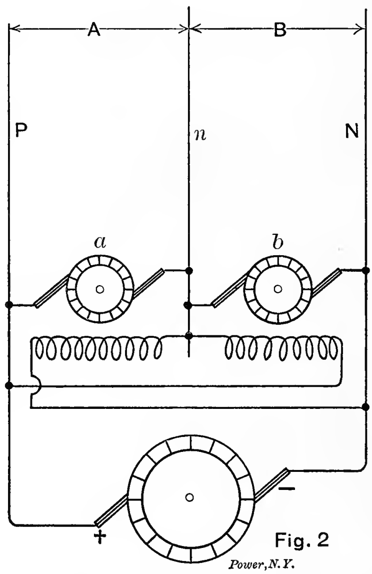


Fig. 2
Power, N. Y.

"That's first-rate, with a little modification," said Jones. "You see it isn't good practice to put a machine to work on full load the first minute it starts up, so we'll put in an alternator and engine in the spare space first and gradually shift the load from the two small dynamos to the alternator. Then the second alternator can go in in place of the little dynamos."

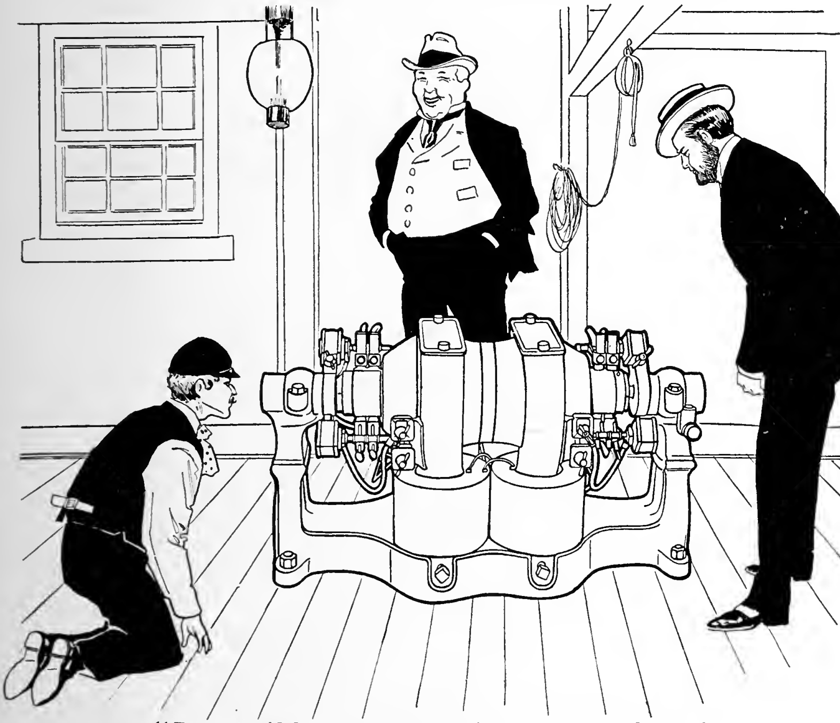
"How about the motor-balancer?"

"You'd better put that in now, so you can shut down your two small dynamos when the day load is small enough for the 230-volt machine to carry alone."

"Have you ordered it?"

"It's at the freight house now," said Jones, with a grin. "I was keeping it hid until you solved your problem."

When the motor-balancer came, both Harvey and the engineer regarded it with much curiosity. Neither had ever seen one of the machines in operation, though the engineer, as above related, knew in a general way how it was connected with the circuit.



"Derned if I can see how the thing regulates."

It did not take much time to install the little machine, and after it was under way the two men bent over it interestedly.

"Derned if I can see how the thing regulates," said Harvey. "May I see the diagram a minute?"

Jones handed him a diagram like Fig. 2.

"Which is the motor?" asked the engineer.

"That depends which side of the three-wire circuit has the lightest load," replied Jones.

"Well, tell us just how the thing works," urged Harvey.

"Suppose both sides are equally loaded," explained Jones; "then both machines will be motors running the common shaft idle. That's clear, isn't it?"

"Yes."

"Now, suppose the side, *A*, has an increase in load, the electromotive force across from *P* to *n* will be lowered, won't it?"

His listeners nodded in unison.

"Then the armature, *a*, will tend to run slower than *b*, but it can't do it because they are rigidly coupled. And *b* can't slack down because the E.M.F. across from *n* to *N* won't let it, so it drives *a* as a dynamo and the E.M.F. of *a* is enough higher than that across the line to nearly balance the two sides."

"Why are the fields cross-connected?" asked the engineer.

"To make the balance better. When the E.M.F. across *A* drops, the field of *b* is weakened and it speeds up until a balance is obtained. The field of *a* is kept up by being connected across *B*, so that the E.M.F. of *a* can't drop when the circuit E.M.F. across *A* drops, as it would do if the fields were connected ordinarily."

Harvey looked at the engineer, and the engineer looked at Harvey.

"Simple, ain't it?" said Jones with his habitual chuckle.

A SIMPLE TROUBLE WITH ANNOYING RESULTS.

One of the new alternators had been duly installed in the Millville station and the incandescent load was being transferred from the direct-current circuit to the alternating-current transformers as rapidly as practicable. Jones was in his happiest humor, being submerged with the work of laying out the alternating-current lines and supervising the installation of the transformers. The engineer was in a state of mixed proud satisfaction and nervous apprehension—satisfaction at the substantial increase in the plant under his care, and apprehension of impending dilemmas with which he might not prove quite capable of dealing properly.

Late one afternoon just after the night load had begun to show up on the ammeter the engineer was surprised by being called up on the telephone by Jones, from the hotel.

"What the deuce ails your alternator?" asked Jones.

"Nothing that I know of," replied the engineer. "What's wrong up there?"

"Lights all dim," reported Jones. "Look at your voltmeter."

The engineer did so.

"It was about half a volt low," he called to Jones through the telephone. "I've raised it to half a volt high; how do they look now?"

"Bare trifle better," replied Jones, "but they're not up by a good deal. See if there are any loose connections beyond the voltmeter, back of the board."

The engineer made a careful inspection of the feeder wires beyond the voltmeter, but could find nothing irregular and so reported to Jones.

"I've tested up here while you were gone from the 'phone," said Jones, "and the voltage is only 97½ now. You'll have to give

your rheostat a twist and run about three volts high to-night. I'll come down in the morning—too tired now."

The engineer did as Jones suggested, and spent an uneasy night as a result of the trouble. Before leaving the station he examined every main connection about the alternator and the switchboard, as well as all of the exciter dynamo connections. Every one was perfectly tight and normal.

The next morning the engineer was at the station bright and early, and Jones arrived soon after, with a placid smile that reassured the engineer greatly.

"Found it?" asked Jones.

The engineer shook his head despondently.

"You'll find it in one of two places," asserted Jones confidently.

The engineer looked at Jones interrogatively.

"It's either a loose compensator connection or a bad joint or connection at the lightning arresters. Sure you looked over the switchboard connections carefully?"

"Dead sure. I went over 'em four or five times."

"Didn't notice the compensator?"

"No; the voltmeter connections were all right though."

"Try the lightning arrester connections?"

The lightning arresters were up in a feeder tower on the roof. "No"; admitted the engineer, "I didn't."

"Compensator's less trouble to get at. Let's look at it first."

The engineer brought a step-ladder and Jones ascended it and took the cover off the compensator. Then he turned and looked down at the engineer, chuckling.

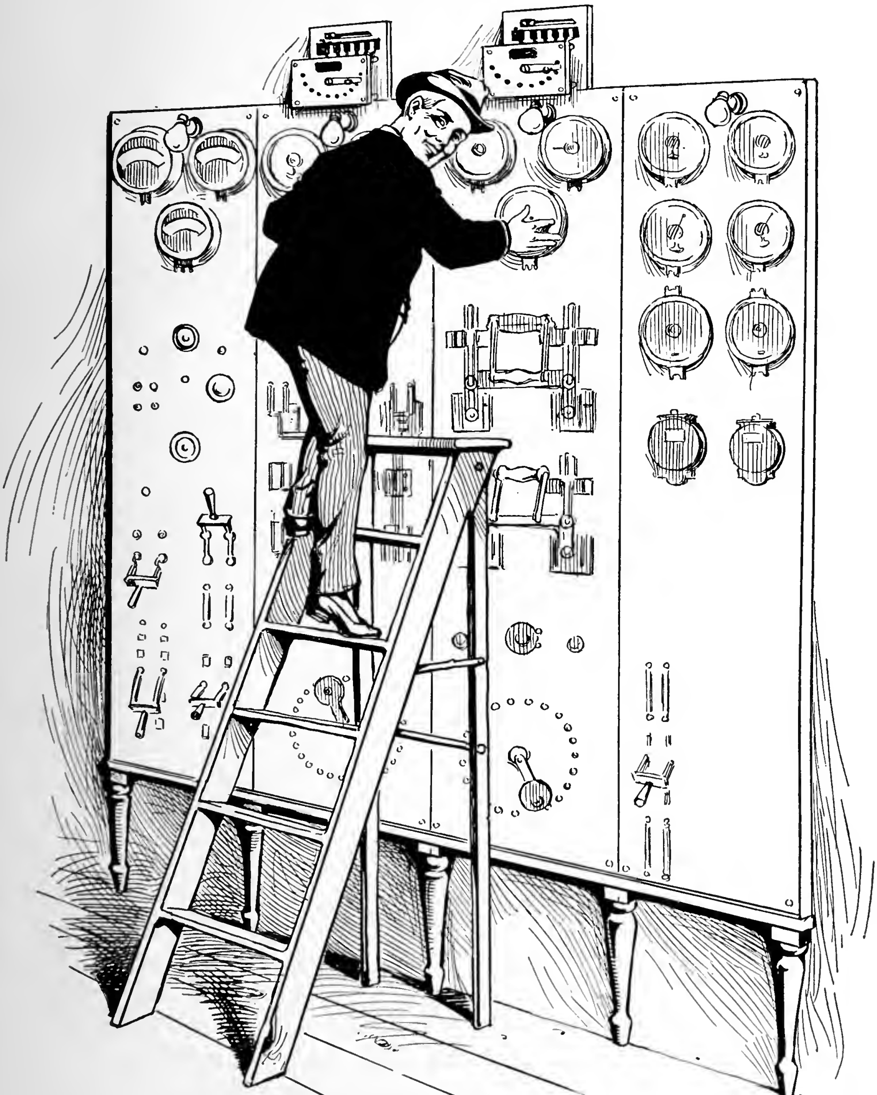
"Told you so," he said, holding the loose end of a wire gingerly between his fingers. Then he switched the compensator out of circuit, put the loose wire in the terminal post, and switched the instrument back in circuit. The voltmeter needle immediately fell back about two volts, and Jones executed a triumphal descent from the top of the ladder, narrowly escaping a tumble in the performance.

"Is it all right now?" asked the engineer.

Jones nodded. "See your voltmeter needle drop?" he asked. "Sorry I didn't get a chance to explain this to you before."

The two went into the engineer's little room and Jones produced from his wallet a sheet on which was a diagram like Fig. 1. The engineer hung over his shoulder in eager anticipation.

"The voltmeter is supplied by a little transformer," said Jones, "which reduces the line voltage to the regular lamp voltage, so that the voltmeter indicates the lamp voltage instead of the line voltage. You knew that, of course."



Jones executed a triumphal descent from the ladder.

"Yes."

"Well; now, in order to avoid using pilot wires from the center of distribution back to the station voltmeter, this compensator is used."

The engineer nodded.

"The voltmeter solenoid has two coils; the main coil is connected to the transformer and the other one to the compensator."

"Yes."

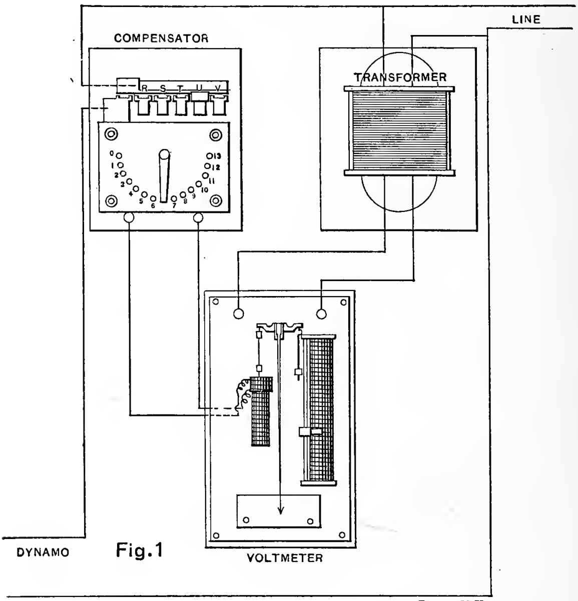


Fig. 1

Power, N.Y.

"The compensator is a transformer with an adjustable primary winding in series with the main line and an adjustable secondary which is connected with the auxiliary coil on the voltmeter."

"How is the winding adjustable?"

Jones sketched Fig. 2.

"Each winding has a lot of taps, so that the number of turns in the primary circuit may be varied by shifting the plug, and the number in the secondary varied by moving the switch."

"What is the object of varying 'em."

"To 'compensate' for different line drops and to adjust for different strengths of primary currents."

"How does the thing compensate for drop?"

"It doesn't literally compensate for the drop. The auxiliary coil on the voltmeter which is fed from the compensator opposes the main coil, and the amount of opposition is such that the needle falls back exactly the amount of your line drop. Therefore, when you strengthen your alternator field and bring the needle up to where it indicates 100 volts, the line voltage is raised just enough to make up for the drop and deliver the normal E.M.F. at the far end of the feeder."

The engineer looked rather confused.

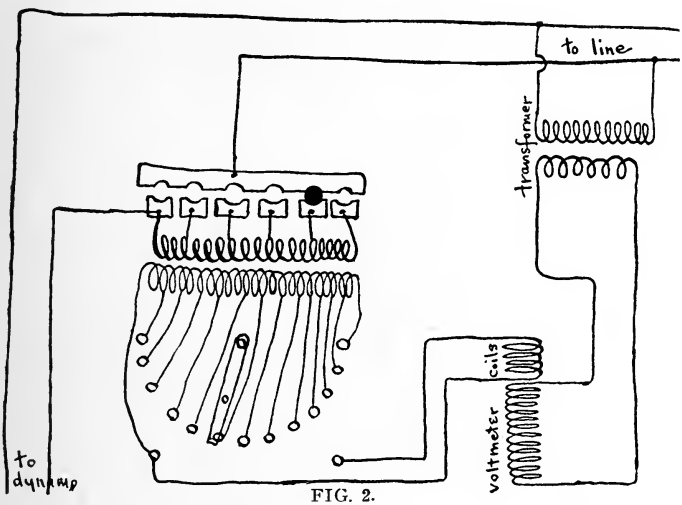


FIG. 2.

"Don't you see it?"

"Not quite."

Jones scratched his head rather impatiently.

"Suppose your line drop is five per cent. If the compensator were left out, your voltmeter would indicate a hundred when in reality the E.M.F. uptown at the lamps was only ninety-five. That's clear, isn't it?"

"Of course."

"Now, with the compensator in, and full load on, the main-line current going through the primary of the compensator induces a current in the secondary that weakens your voltmeter solenoid just enough to make the instrument indicate five per cent short.

Consequently, it indicates what the voltage is *at the lamps* and all you have to do is to bring up your E.M.F. until the needle indicates 100. See?"

"Yes, but how about varying loads?"

"If the full load drop is five per cent, the drop with half load will be two and a half per cent, won't it?"

"Certainly, but the compensator is set for——"

"Never mind that. At full load the compensator weakens your voltmeter five per cent. Now, as the compensator primary is in *series* with the line, at half load the current in it is only one-half the full load current, consequently its secondary effect is only one half——"

"So that the voltmeter is weakened only two and a half per cent, the same as the drop; I see. But if the compensator wire was out of the terminal last night why didn't it open the circuit?"

"Because it was the small wire leading to the voltmeter coil and not the main wire."

"So that it merely disconnected the small coil on the voltmeter and left it indicating the E.M.F. at the switchboard instead of the voltage at the lamps uptown?"

"Precisely so."

TRANSFORMERS ON THREE-WIRE SECONDARIES

"Harvey, do you know anything about transformers?" asked the engineer one afternoon as the railway superintendent wandered into the little den at the power house.

"Divil an atom," disclaimed Harvey, with cheerful indifference. "Do you?"

The engineer shook his head slowly, leaned back and deposited both feet upon the testing bench. "I thought I did know how to connect 'em up together," he said; "not that I had much confidence in my ability to tinker with alternat'n stuff, but I sure did think I could hitch up two transformers together."

"Well, what's shook your faith?"

"Why, I've had two of 'em workin' together up at the sash factory near the junction 'bout a week, 'n' one of 'em's burnt out twice, with pretty near no load; don't even blow the fuses."

"Sure 'twas all right when it went in?"

The engineer nodded emphatically. "First one was bran new; second one was tested all over before it went out there."

"How'd you have 'em connected up?"

"Primaries in series, 'n' secondaries three-wire."

"Thought the primaries had to go in parallel always?"

"They do, gen'rally; but the 2000-volt line don't run out there. The 4,000-volt feeder goin' over to Freeport runs right past the mill, 'n' I put two 2,000-volt transformers there in series."

"Why 'n't you put a 4,000-volt transformer there?"

"Got none."

"What do you use over at Freeport?"

"The voltage comes down to 2,000 right at the blast furnace corner. Step-down transformer there, you know."

"No, I don't know; never heard of one."

"Well, it's simply a special 25-kilowatt transformer that brings the 4,000 volts down to 2,000."

"So you use ordinary transformers over there?"

The engineer nodded.

"What'd you say happened at the sash factory?"

"They got to cutt'n' up monkey shines a couple o' days ago and blew the biggest of the secondary fuses on one side o' the circuit. There were two or three lamps left burnin' on that side, 'n' they busted. The lamps on the other side went out. Just after I got there the transformer on the damaged side begun to smoke 'n' I saved the other one by pullin' the primary switch. Same thing happened yesterday again."

Harvey looked sympathetic but helpless.

"Several persimmons too high for me," he said. "Did you ask Jones about it?"

"Not yet. He's due here to-night, but I hate to be all the time runnin' to him like a baby."

"You're in dead luck to have him to run to," observed Harvey. "You'd find it kinder tough pullin,' sometimes."

"That's all so," admitted the engineer, "but ain't I ever goin' to get so's I c'n paddle my own canoe a few feet without gettin' on a rock?"

Harvey grinned.

"Seems to me you must be graduated pretty soon," he said, "You've had about all the stunts on the programme, ain't you?"

The engineer assented and rose to go out.

"Where to, now?" asked Harvey.

"Goin' to meet Jones. I won't sleep any to-night if I don't get at the bottom o' this derned thing."

Jones arrived duly, and the first thing that met his gaze was the woebegone face of the engineer.

"Hotel's the nearest," said he, interpreting at once the general meaning of the engineer's countenance. "You can tell me all about it while I eat supper."

The engineer restrained himself until Jones had made considerable progress with his meal, knowing that he would get more satisfactory attention by doing so. Then he recited the experience already related to Harvey.

"Hm-m," said Jones. "That's a sort of knocker. Draw me a rough diagram of the transformer connections and fuses."

The engineer drew Fig. 1, and Jones added the reference letters.

"Fuse blew at *x* in the leg *X*, and cut out the lamps on *b?*" asked Jones.

"Yes; that left only two or three lamps on the *B* transformer, from the other branches, 'n' they all busted."

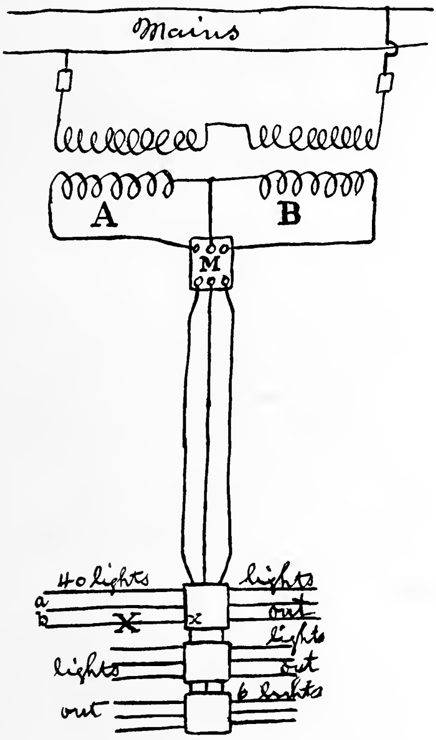


FIG. 1.

"And how many lamps were on *A?*"

"About twenty-eight or thirty."

"They're forty-light transformers, ain't they?"

"Yes."

"No fuses blow at *M?*"

"No."

"Primary fuses all right?"

"Sound as a dollar."

Jones knitted his brows ferociously and gazed intently at the diagram. "Thirty lights on *A* and three on *B*," he muttered. "You say the *B* transformer was the burnt one?" he asked.

"Yes," said the engineer; "just baked to a crisp."

"Hm-m. Guess you'd better leave that with me over night," said Jones. "I'll see if I can shift it by bed-time."

The engineer brightened up. "Then it ain't a simple trouble?" he asked.

Jones shook his head vigorously.

"One of the meanest I've run across in some time," he said.

The engineer went home and slept soundly, feeling satisfied that he could not be considered hopelessly ignorant for failing to solve a problem that gave Jones so much trouble.

Bright and early in the morning Jones was at the station, and his beaming visage told the engineer before he got fairly in the door that the problem was solved.

"My boy," said Jones, with mock solemnity, "I'm an ass. I should have found your trouble immediately, but it took me until one o'clock last night."

"What on earth was it?" asked the engineer.

"Heating of the core. You know that the heating of a transformer core due to the reversals of current increases faster than the voltage, when the voltage is raised, don't you?"

"Ye-es," said the engineer hesitatingly, "but I don't know much about that yet."

"Well, I'll tell you. The heating due to core losses increases almost as the square of the voltage; that is, at twice the proper voltage the core loss heat is a little over three times the heat at normal voltage."

"Well; but the voltage didn't change."

"Don't get excited. You know that as the load on the secondary of a transformer increases, its primary back E.M.F. decreases, allowing more current to flow in the primary?"

"Yes."

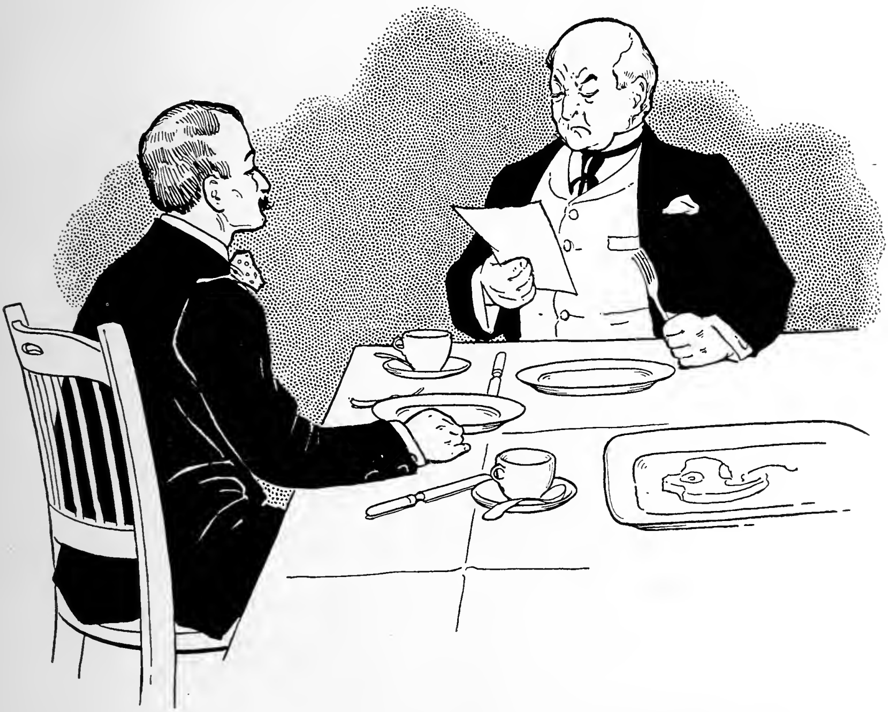
"Therefore, when most of the load was removed from *B* by blowing the fuse, its counter E.M.F. at the primary end became much higher than that of *A*, which remained loaded."

"Yes."

"The primary of *A* tried to pass a considerable current, increasing the back E.M.F. of *B*, so that it was about three times that of *A*."

"Well; I should think that would keep down the primary current and the heating."

"Yes, it kept down the primary current, but the heating wasn't due to that. You know that the counter E.M.F. of a transformer



Jones knitted his brows ferociously and gazed intently at the diagram.

is equal to the impressed E.M.F., minus the extremely small drop due to resistance?"

"Yes."

"Well, the resistance drop is too small to count. However, no matter what the drop is, if the counter E.M.F. of *B* was three times that of *A*, which is entirely probable, the impressed E.M.F. divided itself between them in precisely the same ratio—three to

one—and the result was the same as though you had put the *B* transformer on a 3,000-volt circuit."

The engineer gazed at Jones and emitted a long whistle of amazement.

"What broke the lamps?" he asked.

"The secondary voltage of *B* rose with the primary voltage; if the primary had 3,000 volts the secondary had 150, instead of the usual 100. The breaking of the lamps removed all the load from the *B* transformer, raising its counter E.M.F. still more, and making the core heat worse."

"Well, what'll I do about lighting the factory?"

"Put just as small fuses in the neutral wire as you can—not over half the size of the outside fuses at each cut-out. Then if an outer fuse goes, the current rush in the neutral will blow the neutral fuse and both sides will be thrown out."

A LONG CIRCUIT FROM ORDINARY GENERATORS. TWO-PHASE MOTORS ON SINGLE-PHASE GENERATORS.

"Young man," said Jones to the engineer one day, "I'm going to give you a chance to shine."

The engineer looked apprehensive.

"Is it goin' to be very hard?" he asked, knowing that Jones had some unusual problem in store for him.

"Well," drawled Jones, "it's not so darned easy; but I believe you can do it if you buckle down to it."

"What is it?"

"You know that a feeder's got to be run across the river to Perkins' mill and the little yarn factory for lights and three or four big motors, don't you?"

The engineer nodded assent.

"Well, the distance is too great to deliver direct current, even if you could put poles across in the river, to hold up heavy wires, which you can't; therefore we've got to use the alternating current, and even at that it's going to be somewhat of a problem to get over and deliver enough voltage at the other end. I'm going to let you figure out the way to do it."

"How much drop do you intend to allow?"

"Not over 5 per cent from the switchboard right to the entrances of the two mills. That means delivering about two thousand volts."

"Let's see; there'll be ninety-hundred 'n' ten—twenty-two—a hundred and twenty-two lamps in one mill and about forty in the other. The motors 'll add up about——" here he stopped to make a rough calculation——"Whew! There'll be about sixty ampères in the primary circuit."

"Right," said Jones. "Then what?"

"Why the mills are a good two miles from here!"

"Well?"

The engineer drew his "reference book" from his pocket and consulted a wiring table that Jones had given him when the alternating-current plant was installed.

"The line figures up six hundred 'n' thirty thousand ampère-feet," he said, "and No. 00 wire will only take six hundred 'n' five thousand ampère-feet at 5 per cent drop."

"Exactly," agreed Jones. "This is where your chance to shine comes in."

The engineer scratched his head dubiously.

"No. 00 wire won't hang up across that river," he said, with a perplexed glance through the window at the offending stream. "It's at least a thousand feet across."

"Then you can't use No. 00 wire, of course," said Jones, suggestively.

The engineer looked at him steadily for several minutes, but Jones' countenance gave no clue to a solution of the problem. Suddenly the engineer bethought him of the line running over to Freeport, on which the potential had been raised to 4,000 volts by means of a step-up transformer, and he fairly beamed as he blurted out:

"Step-up transformer!"

Jones shook his head quizzically.

"Game ain't worth the candle," he said. "You're too extravagant."

The engineer looked crestfallen, and Jones hastened to reassure him.

"You're not so far out of the way," he said; "don't get discouraged so quickly. What would you do in the case of a railway feeder that had too much drop?" he continued, in order to help the engineer along.

"Put in a boost—well, I'll be jiggered," in high disgust; "I did think I had more sense 'n to take all day to a thing as simple as that."

Jones grinned cheerfully.

"What kind of a booster would you use?" asked he.

"Transformer, of course," said the engineer promptly, drawing a commendatory series of vigorous nods from Jones.

"All right so far," said the latter. "Now draw me a diagram of your transformer connections and figure out the size of your wires."

The engineer drew the diagram shown by Fig. 1, handed it over to Jones and waited for a verdict.

"Correct," said Jones. "That raises your voltage to——"

"Twenty one hundred," cut in the engineer.

"Not exactly. Remember that your switchboard voltage is over two thousand; you are delivering two thousand to your transformers uptown. What is the switchboard voltage? About twenty-one hundred, ain't it?"

"Twenty-one hundred 'n' ten at full load."

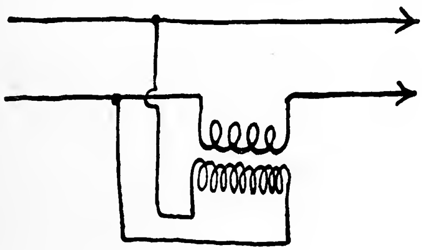


FIG. 1.

"Then the booster will raise you to twenty-two hundred and ten, and you have a margin of two hundred and ten volts for your drop in order to deliver two thousand volts at the mills. Remember, though, that the most of your drop must go in the wires across the river because they must be small."

"I can run steel cables across to hang the copper wires from," suggested the engineer.

"That's good; but your copper wires must be pretty small so that they won't break down the steel ones."

The engineer spent several minutes figuring on the tensile strength of steel cables, the weight of line wires, etc., and finally drew a long breath. "It won't be safe to run anything bigger 'n' a No. 8 wire across there hung on steel rope," he said, "unless I use a rope as big as my arm."

Jones nodded and said not a word.

"No. 8 wire," continued the engineer, "eleven hundred feet long with a load of sixty ampères, has sixty-six thousand ampère-feet, 'n' that means a drop of 4 per cent right there."

"How many volts of drop is that?" asked Jones suggestively.

"Oh, that's so; it's only eighty volts, 'n' we've got a margin of two hundred 'n' ten," brightening up. "Why, that's a cinch. I c'n put in just as big wires as I please on the other side o' the river, so's to keep the total drop down to two hundred 'n' ten."

"That's all right, so far," said Jones. "You can work out the land wires any time, but you mustn't forget that the self-induction of the line itself will increase your drop considerably—about two or three per cent of the drop itself. Now you've got the right idea it won't be any trouble for you to get that fixed up all right. The next thing is to consider how you're going to arrange about the motors across in the mills. Then again, you want to arrange to cut out your booster transformer every night after the motors have been shut off so you won't be pumping juice through the booster and wasting that much energy; besides, with only the night lamps in circuit over there you can't have such a high voltage as the booster would give."

"Easy enough to cut out the booster," said the engineer. "Simply put a switch in the primary and cut her out with it."

Jones handed him back the diagram.

"Look at your connections again and see if you think that'll cut it off," he said.

"The secondary 'll be in series with the line," said the engineer, "but it hasn't enough resistance to amount to anything."

"No; but the resistance doesn't amount to anything much anyhow," said Jones. "Your secondary has exactly the same effect on the core that the primary has, and with the primary open the core losses 'll keep on just the same. Worse still, the secondary acts as a choking coil if the primary is open, and it would cut down the voltage on your line, even with a very small load going through. Draw me a diagram of an arrangement to cut out both the primary and secondary at one operation with a single switch and without opening the line."

The engineer labored mentally for awhile, and finally produced the diagram shown by Fig. 2.

"Good boy," said Jones heartily. "Now for the motor business."

"That's one too many for me," said the engineer positively. "I dunno a thing about 'em. Didn't know they used motors on single-phase lines."

The engineer got up and fairly danced in his admiration.

"Yes; they do, all right; but we're not going to run any single-phase motors around here!"

The engineer looked puzzled.

"Aren't the alternators single-phase machines?" he asked.

"Yes; but there are two of them. See?"

The engineer didn't see for some little time. Then he gave vent to a long whistle. "Well, I'll be——"

"No, you needn't," interrupted Jones; "you've been jiggered once to-day. What's the matter?"

"You're goin' to run a two-phase circuit off'n the two alternators, ain't you?"

"Precisely; why not?"

"How'll you keep the two phases right?"

"Couple the shafts with a sliding dental clutch, made so that they can't couple but one way—exactly right to give two phases a quarter of a cycle apart."

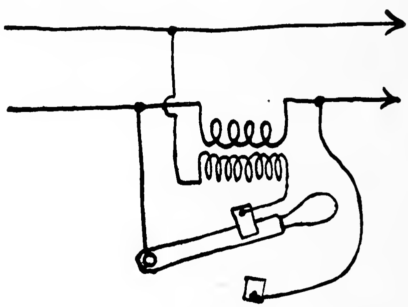


FIG. 2.

The engineer got up and fairly danced in his admiration.

"Gee whiz! what a scheme," he exclaimed. Great Moses! then we c'n supply two-phase motors all around the edge o' town where it's too far for the direct-current lines to run. Sufferin' snakes! won't that take Harvey's hat off!"

"How's that?"

"He's been crowin' aroun' here for a week, threat'nin' to put in 500-volt motors in the little factories out on the fair ground branch 'cause I wouldn't run the power circuit out there. Now I've got him. But, say," suddenly sobering down, "won't alternat'n'-current motors knock out the voltage on that line across the river?"

"You mean make the drop worse?"

The engineer nodded

"It might if we used induction motors alone, but I'm going to

put synchronous motors in the yarn factory and adjust 'em to neutralize the effect of the induction motors in Perkins' mill. Tell you about that next time I come down."

L. of C.

INCREASING THE OUTPUT OF AN ALTERNATOR. WIPING OUT INDUCTIVE DROP.

The plant at Millville had run along for several months "without even an incident," as Harvey expressed it, when Jones appeared in the doorway of the engineer's "den" one morning and asked:

"How fast is your load growing?"

The engineer, having become accustomed to Jones' methods of attack, merely reached for his station record book, consulted it, and replied:

"Mighty slow, if at all. We've got about everything there is except the little cotton mill."

"Well, you'll get that soon. I've practically sold 'em the motors."

The engineer scratched his nose reflectively.

"How much power'll they want?" he asked.

"About 25 horse-power."

"Can't pull 'em."

"You'll have to," asserted Jones, with a grin.

" 'Nother problem?" queried the engineer.

Jones nodded.

How much do you lack of full load on the alternators?" he asked.

"About five ampères on the switchboard ammeter."

"That's about 11,000 watts; say 10,000 watts available."

The engineer assented.

"That means about 13 horse-power," continued Jones. "Now, your engines and boilers are big enough for a considerable increase in load beyond the capacity of the alternators; I took care of that when they went in."

"That's right," agreed the engineer, "but that don't help the alternators out, does it?"

"No, but it enables us to help 'em out," said Jones.

The engineer scratched his nose reflectively.

"Change 'em for bigger ones?" asked the engineer.

"Nope."

"Rewind the armatures with heavier wire and run 'em faster?"

"No; that would run your frequency up too high."

The engineer looked through the door at the alternators; then at Jones' imperturbable countenance. Then he blew his nose in a helpless sort of fashion and said:

"I give it up."

Jones sniffed disappointedly.

"I thought you were gamer than that," he said.

"I've guessed the only ways I know to raise the capacity," said the engineer, somewhat abashed.

"No, you haven't," said Jones. "You know the way to do it perfectly well, but you haven't remembered it, that's all."

The engineer was more puzzled than ever.

"It's a case of changing something, of course," continued Jones. "The output of a machine can't be increased without making a change in it somewhere."

"There's nothin' to change but the armature that'll change the output," suggested the engineer.

"Certainly not—at least, in a machine already built."

"Well, I don't see how it can be changed to give more current without rewinding it."

"Or substituting another armature with a different winding," said Jones. "You're slow to-day."

The engineer thought it over until he was nearly addled, and finally suggested timidly:

"Two-phase armature?"

"Of course; you know as well as I do that a two-phase armature has more output than a simple winding, because the wires fill all of the space around the whole armature surface. How much of the circumference is occupied by wires in your single-phase armatures?"

"About four-fifths."

"Then if you have two windings, each covering half of the armature, you'll have——"

"One-fifth more wire than there is now," broke in the engineer.

"Your arithmetic is bad."

The engineer stared.

"Suppose it took five hundred wires to cover the armature," said Jones, "your single-phase armature would have about four hundred, eh?"

"Yes."

"Now, if you add the other hundred, is that adding only a fifth?"

"Guess I must be 'dopey,'" said the engineer, sheepishly. "Do you mean a two-phase armature 'll give a fourth more output 'n a single-phase, same size?" he asked.

"No," said Jones, "it won't. I was only correcting your arithmetic. But it'll give about eighteen or twenty per cent more output, and that'll be a-plenty to carry all the load you'll get for six or eight years."

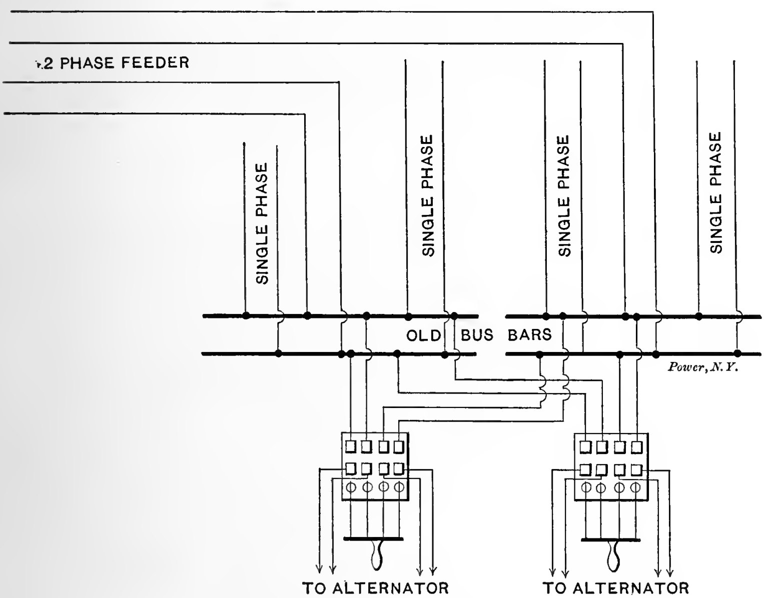


FIG. 1.

"How'll we connect the machines at the board?" asked the engineer.

"Divide up your single-phase circuits between the two phases and use one pair of your bus-bars for one phase and the other pair for the other phase."

"And run the machines together?"

"Yes; this way," and Jones drew Fig. 1. "You see, you won't have to change a thing on the face of the board except the alternator main switches. The feeders can be divided between the two

phases on the back of the board. We'll have to put in synchronizing lamps so you can tell when to throw the switch."

In the course of a few weeks the change was made and Jones took advantage of a light-load part of the day, when only one alternator was needed, to show the engineer how to put the two machines in parallel. He started up the second machine and threw it in circuit with the working alternator, then cut it out and shut down, going through this process several times so that the object lesson might be thorough. Then he turned the machine over to the engineer for a trial.

The first attempt was successful, but the engineer was so excited that his knees almost wobbled. Cutting out the machine, he signaled his assistant at the engine throttle to close down and open up again. The phasing lamps began to flicker as the alternator approached synchronism, the flickering becoming slower and slower, slower and slower, until the engineer in his nervousness closed the switch just as the lamps *went out*.* There was an ear-splitting screech from the belts, a subdued roar from the armatures and a final bang from the fuses; the boy at the throttle fled incontinently, Jones walked coolly to the engines and shut them both down, and the engineer leaned weakly against the switchboard.

"Get a move on and put in fresh fuses," called Jones, who was rapidly looking over the alternators.

The engineer did so, opened the alternator switches, and started up the engines again, Jones having found no signs of damage. Nothing had been harmed, and after a few more "object lessons" by Jones the engineer became more confident and performed the operation of "coupling up" several times without a "misfire."

"All you need's a little more nerve," said Jones. "Now, let's go inside while I tell you about those synchronous motors across the river."

They went into the engineer's little room, and Jones put his feet on the desk, preparatory to delivering his homily.

"You know, of course, that in an alternating-current circuit the current constantly reverses, passing from nothing to maximum in one direction and back to zero, then to maximum in the opposite

* In some plants the phasing lamps are connected so as to show no light when the alternators are in phase. In this narrative the opposite condition is assumed, *i. e.*, the lamps light up when the alternators are in phase.

direction and back to zero, then in the first direction, and so on."

The engineer said he understood that.

"Do you know, too, that the current in a circuit does not always reverse its polarity at the same instant with the reversal of the E. M. F. of the circuit?"

"I know it's so, but I don't understand why," said the engineer.

"Well, that lagging of the current reversal behind the voltage reversal is caused by self-induction in the circuit."

"When magnets are used in a circuit?"

"Yes. A coil of wire without any core has a good deal of self-induction, but when it has a core it is hundreds of times worse. Now, do you know what electrostatic capacity is?"

"N—no. I've read about it, but it's too rich for my blood."

"Well, you don't need to be a scientist to run a plant. Capacity, as it's called for short, is almost the opposite of self-induction—electricians call it negative reactance, and reactance is the result of self-induction."

"Yes; I know that much."

"All right. Now, capacity has the opposite effect on the relation between E. M. F. and current from that of self-induction—it pulls the current ahead of the voltage so that it actually reverses ahead of it. Now, you can easily see that if inductance or self-induction pulls the current reversals back—retards them—and capacity pulls them ahead—advances them—it is possible to balance one by the other and have your current reverse precisely with the E. M. F. See?"

The engineer "saw," and expressed his admiration.

"Now, a synchronous motor can be made to give a circuit electrostatic capacity, but an induction motor always gives it self-induction or reactance, whichever you choose to consider."

"What's the difference?" broke in the engineer.

"Why, you know. Self-induction is the cutting of magnetic lines by the wires of the coil that produces the magnetic lines. Reactance is the opposition which this process offers to the passage of current through the coil, just as resistance is the opposition of the wire itself to the passage of current. Now, let's get back. If you have induction motors on a line, they introduce a lot of self-induction, and make the reversals of current lag behind the reversals of E. M. F. If you add synchronous motors to the circuit

and adjust them to give a *capacity* effect, you can neutralize the self-induction and get rid of that lag."

"How do you adjust them for capacity?"

"Strengthen the field-magnets beyond the point necessary for ordinary working."

The engineer gazed thoughtfully at Jones' sparse forelock and remembered the care with which his instructor had adjusted the fields of the synchronous motors in the mill across the river. He was aroused by the banging of Jones' heels on the floor as he abandoned his lounging attitude and arose.

"Well, my boy," said Jones, as he struggled into his overcoat, "I'm going to leave you alone for a long time now. I've about worked out the field around here, and you've got to a point where you don't need any help, except in case of some very unusual trouble.

"Always remember to keep cool, no matter what happens. If anything goes wrong, think it over first and get scared afterwards. Any time you get into a serious hole, telegraph me at the home office and I'll come as soon as possible. But don't get rattled. Good-by," and with characteristic abruptness Jones grabbed the engineer's hand vigorously and was gone.

The engineer watched his going with a heavy heart and feeling as though a large part of the earth had been suddenly snatched away immediately in front of him, leaving him tottering on the edge of a chasm.

June - 8 . 1901

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